Appendix K
Disposal Cell Groundwater Monitoring Plan

DOE/GJ/79491-646

Weldon Spring Site Remedial Action Project

Weldon Spring Site Disposal Cell Groundwater Monitoring Plan

Revision 2

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ABSTRACT

The *Weldon Spring Site Disposal Cell Groundwater Monitoring Plan , Rev. 2* describes the approach that will be used to develop tolerance limits on concentrations of contaminants for the cell groundwater monitoring network; the sampling strategy to be implemented for compliance with long-term groundwater monitoring requirements; and outlines the statistical methods to be used in data analysis. The Plan also identifies monitoring well locations, depths and construction details.

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1. INTRODUCTION

1.1 Scope

This plan describes the disposal cell groundwater monitoring program for the U.S. Department of Energy's (DOE's) Weldon Spring Site, which is being conducted according to the substantive requirements of 40 CFR 264, Subpart F, and 10 CSR 25-7.264(2)(F). This plan includes a description of the sampling locations, frequency, parameters, and associated analysis and sampling procedures. A discussion about the data evaluation and the development of the evaluation approach are also included.

1.2 Purpose

The purpose of this plan is to summarize the disposal cell groundwater monitoring program. The following specific elements are addressed: the design of the monitoring network; the results of baseline monitoring; the long-term monitoring program, which includes detection monitoring, compliance monitoring, and corrective action; and data review and reporting.

1.3 Applicable or Relevant and Appropriate Requirements

In the *Record of Decision for the Chemical Plant Area of the Weldon Spring Site* (Ref. 1), the substantive requirements of 40 CFR 264, Subpart F of the *Resource Conservation and Recovery Act (RCRA)*, and 10 CSR 25-7.264(2)(F) of the Missouri Hazardous Waste Regulations, were identified as applicable or relevant and appropriate requirements (ARARs) for the selected remedy (i.e., construction and operation of an engineered disposal cell). Table 1-1 provides a summary of these ARARs and indicates the sections of this plan that discuss the strategy for meeting each requirement. In addition to these ARARs, relevant portions of 10 CSR 80-3.010(8) were also used as guidance in developing this monitoring plan.

1.4 Background

Groundwater at the chemical plant is contaminated with trichloroethylene (TCE), nitrate, uranium, and nitroaromatic compounds. The groundwater contamination originated with the Raffinate Pits and other source areas of the chemical plant site and former ordnance works area, that have been removed. Contamination is primarily limited to the weathered portion of the uppermost bedrock unit, the Burlington-Keokuk Limestone. Nitroaromatic compounds are present east and north of the disposal cell and is elevated in several of the disposal cell monitoring wells. Nitrate is present north and west of the disposal cell and is elevated in several of the disposal cell monitoring wells. Uranium is present southwest of the disposal cell; however, elevated levels are not observed in any of the disposal cell monitoring wells. TCE is also present southwest of the disposal cell, but elevated levels are not observed in any of the disposal cell monitoring wells.

Table 1-1 ARARs Summary for Disposal Cell Groundwater Monitoring

SUMMARY OF REGULATION	PERTINENT SECTION OF MONITORING PLAN
40 CFR 264.90 APPLICABILITY Specifies the applicability requirements and exemptions for owners or operators of facilities that treat, store, or dispose of hazardous waste.	Section 1.3, Applicable or Relevant and Appropriate Requirements
40 CFR 264.91 REQUIRED PROGRAMS Specifies the criteria for determining which monitoring and response program (i.e., detection monitoring, compliance monitoring, or corrective action) should be instituted at a regulated facility.	Section 4.0, Detection Monitoring Program Section 5.0, Compliance Monitoring and Corrective Action Programs
40 CFR 264.92 GROUNDWATER PROTECTION STANDARD Requires compliance with certain conditions when hazardous constituents are detected in groundwater underlying a regulated unit.	Section 5.0, Compliance Monitoring and Corrective Action Programs
40 CFR 264.93 HAZARDOUS CONSTITUENTS Specifies the criteria for defining "hazardous constituents" to which the groundwater protection standard applies.	Section 5.0, Compliance Monitoring and Corrective Action Programs
40 CFR 264.94 CONCENTRATION LIMITS Specifies the criteria for establishing concentration limits for hazardous constituents detected in the groundwater underlying a regulated unit.	Section 3.3.3, Revised Baseline Tolerance Limits
40 CFR 264.95 POINT OF COMPLIANCE Defines the point of compliance at which the groundwater protection standard applies and monitoring must be conducted.	Section 2.2, Groundwater Monitoring Wells
40 CFR 264.96 COMPLIANCE PERIOD Defines the compliance period during which the groundwater protection standard applies.	Section 5.0, Compliance Monitoring and Corrective Action Programs
40 CFR 264.97 GENERAL GROUNDWATER MONITORING REQUIREMENTS Specifies general requirements for the groundwater monitoring program, such as well installation, sampling and analysis procedures, determination of groundwater surface elevation, and statistical methods to be used.	Section 2.0, Monitoring Network Design Section 3.3.3, Revised Baseline Tolerance Limits Section 4.4, Groundwater Elevation Measurements Section 6.0, Quality Control
40 CFR 264.98 DETECTION MONITORING PROGRAM Specifies requirements for detection monitoring programs, including monitoring parameters, sampling frequency, determination of groundwater flow, determination of statistically significant evidence of contamination, and required response to positive evidence of contamination.	Section 4.0, Detection Monitoring Program
40 CFR 264.99 COMPLIANCE MONITORING PROGRAM Specifies requirements for compliance monitoring programs, including monitoring parameters, sampling frequency, determination of groundwater flow, determination of statistically significant evidence of contamination, and required response to exceedance of the groundwater protection standard.	Section 5.0, Compliance Monitoring and Corrective Action Programs
40 CFR 264.100 CORRECTIVE ACTION Specifies requirements for corrective actions to be instituted to ensure compliance with the groundwater protection standard.	Section 5.0, Compliance Monitoring and Corrective Action Programs
10 CSR 25-7.264(2)(F) RELEASES FROM SOLID WASTE MANAGEMENT UNITS Specifies that efforts made to monitor groundwater or implement corrective action be documented, and that daily precipitation be measured. Also requires a surface water monitoring program to represent the quality of surface water hydrologically downgradient of the facility.	Section 2.3, Surface Water Monitoring Location Section 4.5, Precipitation Data Section 4.8, Detection Monitoring Reporting Section 5.0, Compliance Monitoring and Corrective Action Programs

2. MONITORING NETWORK DESIGN

Groundwater monitoring requirements under 40 CFR 264, Subpart F, of the *Resource Conservation and Recovery Act* (RCRA) specify that the monitoring system for a regulated unit must "consist of a sufficient number of wells, installed at appropriate locations and depths, to yield groundwater samples from the uppermost aquifer that: (1) represent the quality of background water that has not been affected by leakage from the regulated unit…; (2) represent the quality of groundwater passing the point of compliance; and (3) allow for the detection of contamination when hazardous waste or hazardous constituents have migrated from the waste management area to the uppermost aquifer." The disposal cell monitoring network at the Weldon Spring Site has been designed to meet these requirements, as described below.

2.1 Basis of Design

The following criteria constitute the basis for design of the disposal cell groundwater monitoring network at the Weldon Spring Site:

- Regulatory requirements,
- Potentiometric surface of the shallow groundwater beneath the disposal cell,
- Design aspects of the disposal cell, and
- Physical site conditions.

The Subpart F regulations of RCRA specify that groundwater monitoring must be conducted at the point of compliance, which consists of a vertical surface that is located hydraulically downgradient of the waste management area and extends down into the uppermost aquifer. The RCRA regulations provide flexibility regarding the number, spacing, and depths of monitoring wells; however, the Missouri Sanitary Landfill regulations in 10 CSR 80-3.010, specify a minimum of one upgradient and three downgradient wells for landfills. The disposal cell network was designed to incorporate one upgradient and four downgradient wells, allowing for the possibility that wells could be added or removed as necessary. Since the original network was installed, two wells have been added and two have been eliminated. Thus, the current network still consists of one upgradient well and four downgradient wells. The location of these wells is discussed in Section 2.2.

To supplement groundwater monitoring, Missouri Hazardous Waste regulations in 10 CSR 25-7.264(2)(F) require that a surface water component be included in monitoring releases from waste management units. The surface water monitoring system must "consist of a sufficient number of points at appropriate locations to yield surface water samples that: (a) represent the quality of background surface water that has not been affected by any contamination from the facility…; and (b) represent the quality of surface water hydrologically downgradient of the facility or regulated units." The surface water monitoring location incorporated in this plan is discussed in Section 2.3.

The potentiometric surface of the shallow groundwater indicates that the flow gradient beneath the disposal cell is generally to the north and northwest, as shown in Figure 2-1. The general direction of groundwater flow has remained relatively unchanged since the cell monitoring system was designed, throughout remediation of the site and construction of the disposal cell. However, since construction of the disposal cell and previous remedial activities, the groundwater elevation has decreased due to dewatering of ponds/basins and diversion of surface water flow and reduced infiltration (recharge) to the shallow aquifer.

Design aspects of the disposal cell that were considered in determining the original locations of the monitoring wells included the locations of the clean fill dikes and leachate collection sump, the 1% to 1.5% northward slope along the base of the cell, and the double liner/leachate collection system. Since the monitoring network was installed while physical site conditions were undergoing frequent change due to remediation and construction activities, existing and planned locations of excavations, roads, structures, surface water bodies, staging areas, and the footprint of the disposal cell were also considered to ensure availability and access to the planned monitoring locations.

2.2 Groundwater Monitoring Wells

The original disposal cell monitoring network was established in 1996. It included five wells: one upgradient well (MW-2048) and four downgradient wells (MW-2032, MW-2045, MW-2046, and MW-2047). The well locations, which are shown in Figure 2-2, were chosen based on the criteria discussed above. Well MW-2048 was installed south of the cell to monitor water quality upgradient of the disposal cell. Wells MW-2045, MW-2046, and MW-2047 were installed northeast, north, and northwest of the cell, respectively, to monitor potential groundwater impacts downgradient of the disposal cell. Well MW-2032 was an existing well that was retained to monitor potential groundwater impacts downgradient (i.e., north) of the leachate sump. Figure 2-3 provides a cross-sectional view of the monitoring system, in relation to the disposal cell and leachate sump.

While the original monitoring network consisted of five wells, it was the intent of the plan to provide flexibility for reacting to the dynamics of the system being monitored. The heterogeneous nature of the fractured bedrock aquifer and the complexities associated with monitoring a previously contaminated groundwater system created uncertainty in the actual performance of the proposed monitoring wells. Additional wells were to be incorporated into the network on an as-needed basis during both the active life and the post-closure period to replace or supplement data from poorly performing wells. Thus, since MW-2045 demonstrated consistently poor hydraulic performance and yielded widely variable analytical data, a fifth downgradient well (MW-2051) was installed in 2001 northeast of the disposal cell, as shown in Figure 2-2. Under the present revision of this plan, MW-2051 replaces MW-2045 as the monitoring location for the northeast side of the disposal cell. Monitoring well MW-2051 exhibits higher hydraulic conductivities and will better represent the shallow groundwater system than MW-2045.

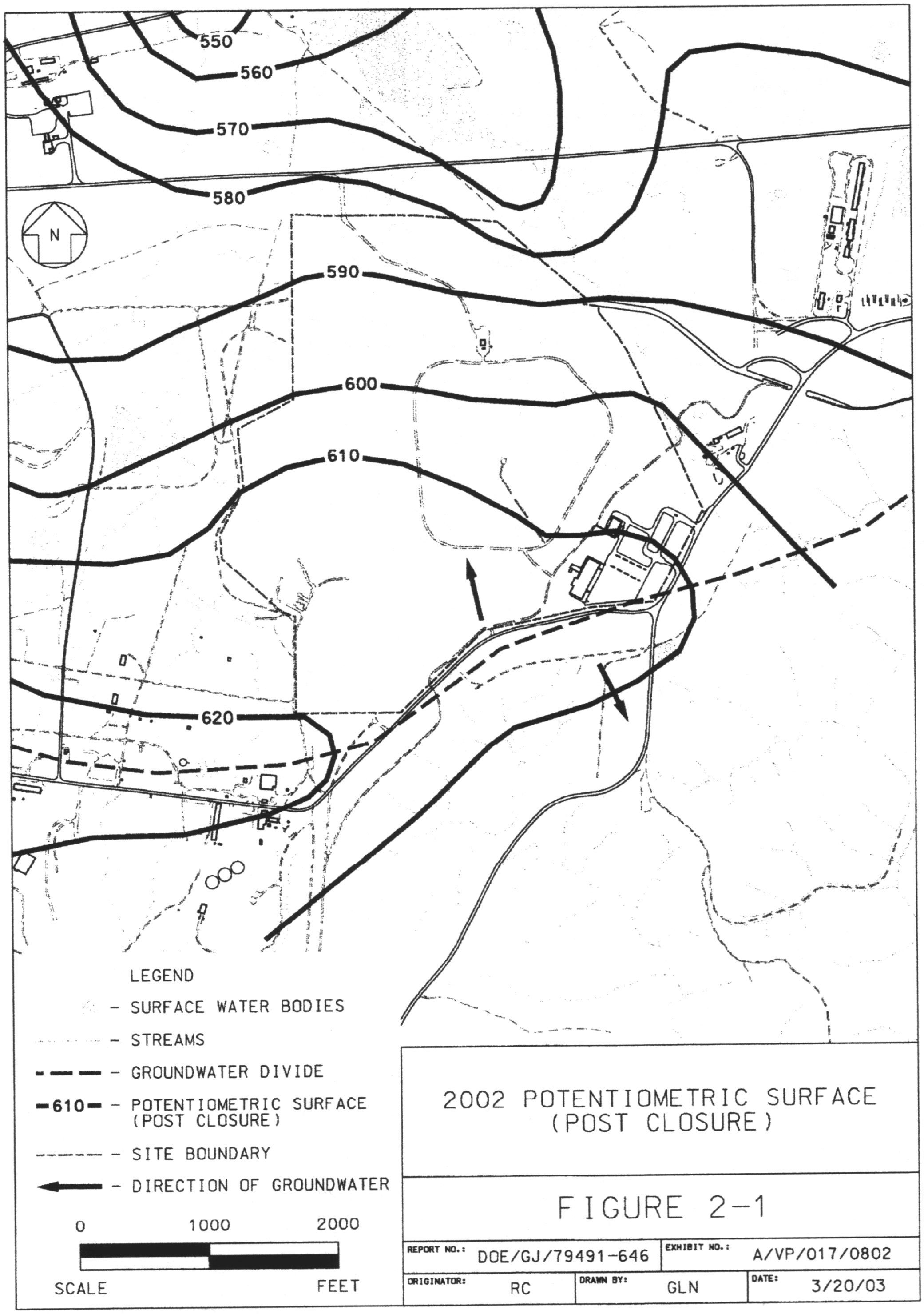

Figure 2-1 2002 Potentiometric Surface (Post Closure)

The original upgradient well, MW-2048 was damaged during construction activities in 2001. This well was determined to be damaged beyond repair, which led to its abandonment and installation of a replacement well shortly thereafter. The new well, MW-2055, is located approximately 20 feet upgradient (i.e., south) of MW-2048 and has replaced it as the upgradient monitoring well (see Figure 2-2). Data review conducted for both monitoring wells indicated comparable upgradient water quality. No PCBs, PAHs or nitroaromatic compounds were detected at either location. Concentration ranges of ions, metals, radiological and indicator parameters were similar, with the exception of three metals (iron, manganese, and nickel) and one indicator parameter (total organic carbon). However, the concentrations are within typical ranges for the groundwater in the weathered Burlington-Keokuk Limestone.

All wells in the disposal cell monitoring network were installed and developed in accordance with 10 CSR 23, *Missouri Water Well Construction Code*. Each well is constructed of 2-inch ID Grade 316 stainless steel casing, with a 10-foot length of 0.010-inch slotted screen. Total depths of the wells range from approximately 45 to 75 feet below ground surface, depending on the respective depth to water at each location. Borehole logs, well diagrams, packer test calculations, and well development forms for the original wells are contained in the *WSSRAP Disposal Cell Monitoring Well Program Installation Report* (Ref. 2). Appendix A of this plan contains the well diagrams, packer test calculations, and well development forms for the two newly installed wells, as well as the borehole logs for all disposal cell wells.

2.3 Surface Water Monitoring Location

The surface water location used to detect downgradient impacts from the disposal cell is Burgermeister Spring (SP-6301) (see Figure 2-4). Historical dye tests have indicated that this spring is the primary localized point of emergence for groundwater from the vicinity of the chemical plant (Ref. 3). Thus, sampling of Burgermeister Spring will yield results that are representative of both surface water and groundwater hydraulically downgradient of the disposal cell. Burgermeister Spring represents the first surface water impacted by groundwater originating from the site, including the disposal cell area. Downstream Lake 34 was not chosen as a monitoring point as Burgermeister Spring represents the worst case conditions for surface water and Lake 34 does not receive surface water contribution from the chemical plant area. It is common practice in aquifer systems dominated by fracture or conduit flow to supplement the monitoring well system by sampling springs that are hydraulically connected to the uppermost aquifer and that have shown a connection to the facility (Ref. 17). This spring has been monitored routinely since 1987 under the *Environmental Monitoring Plan* (Ref. 4), which contains the overall environmental monitoring requirements for the Weldon Spring site and is a long-term monitoring locations for the Groundwater Operable Unit. There is no upgradient surface water body included in this monitoring plan. The disposal cell is situated near both the regional surface water and groundwater divides; therefore, no surface water bodies are located upgradient of the disposal cell.

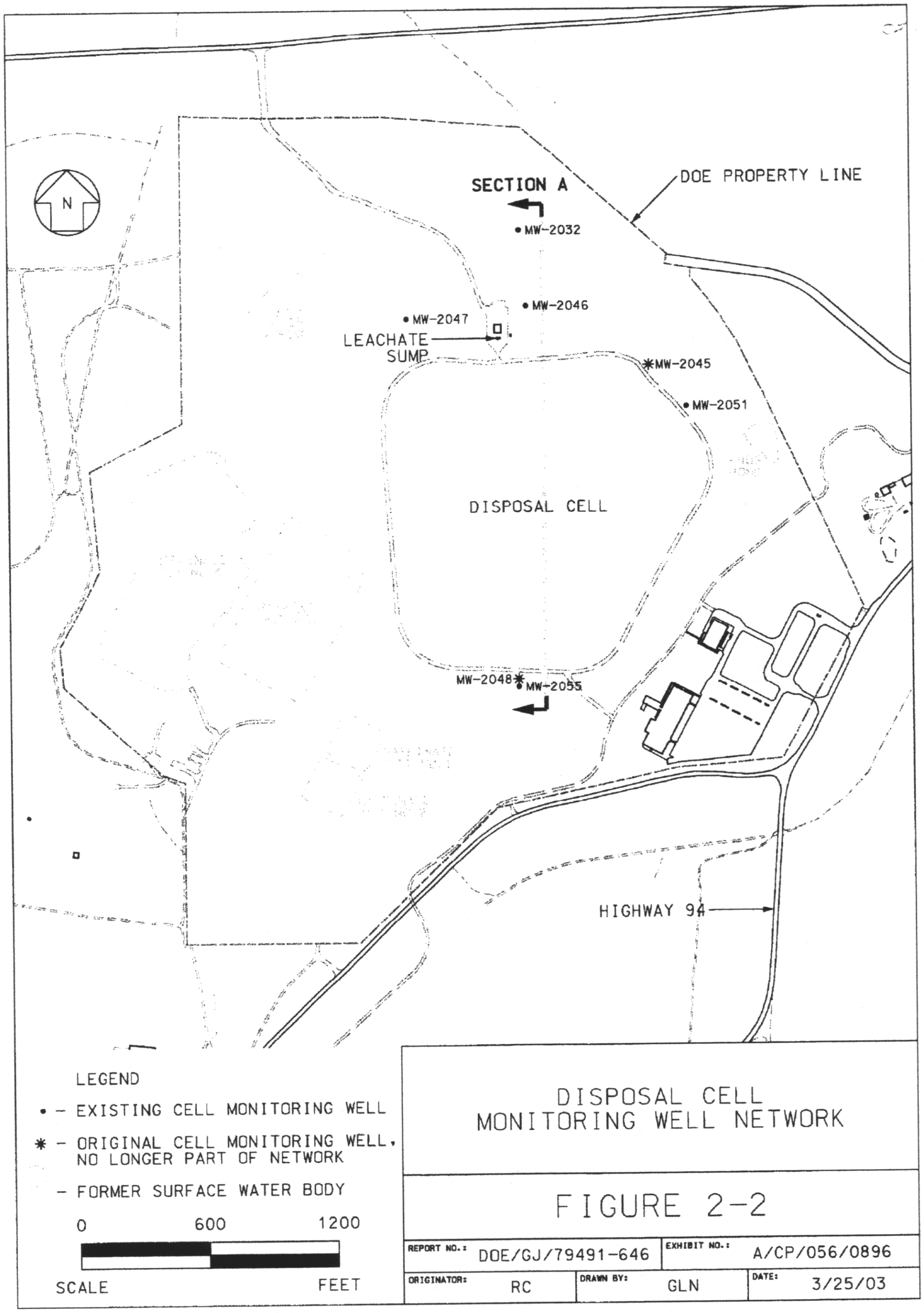

Figure 2-2 Disposal Cell Monitoring Well Network

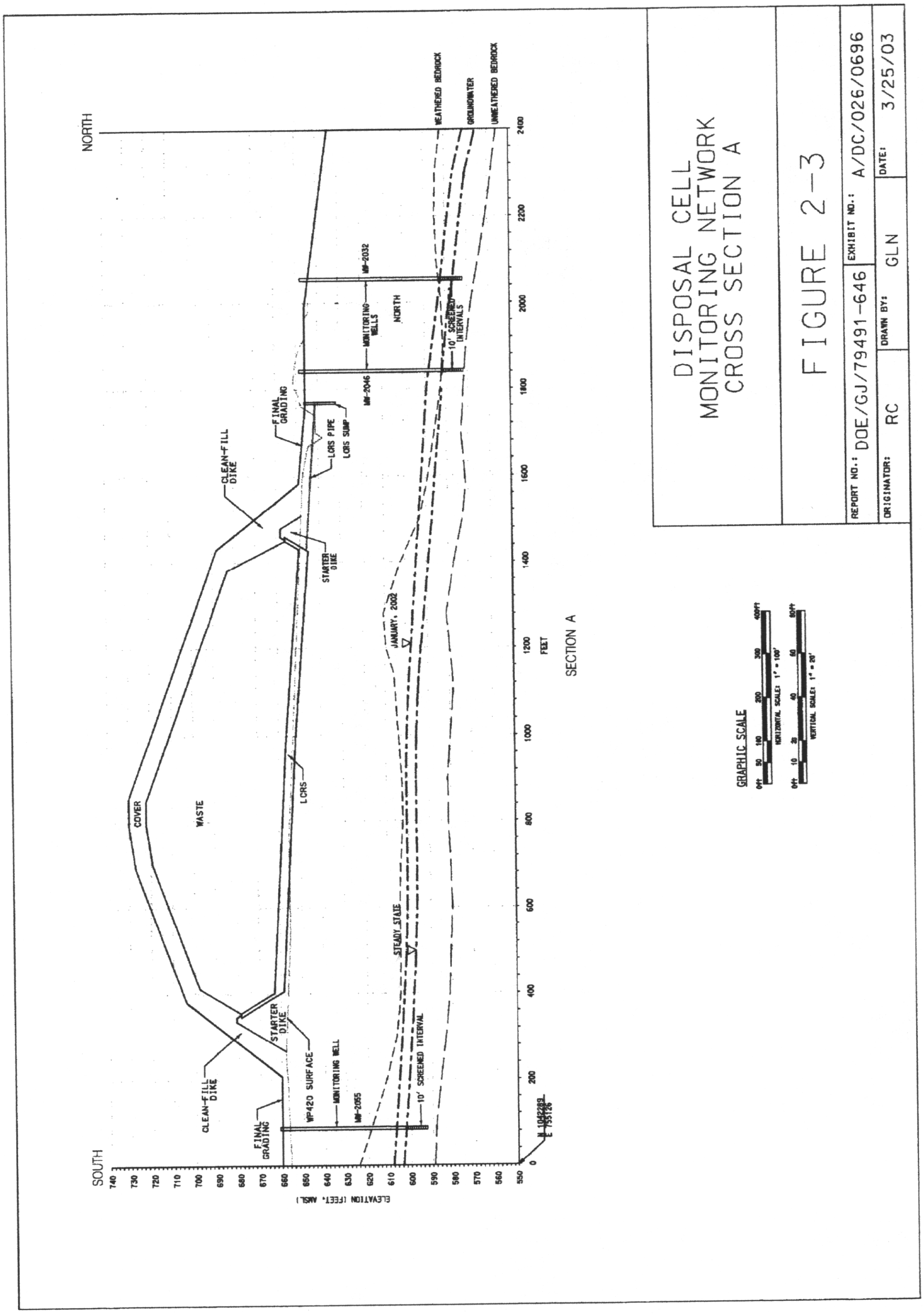

Figure 2-3 Disposal Cell Monitoring Network Cross Section A

Ecological evaluations (including toxicity testing) for Burgermeister Spring have been conducted previously under site environmental monitoring and remedial investigation programs, and these results may be used for a determination of baseline ecological conditions for this plan. Results of ecological studies conducted for Burgermeister Spring as part of the *Remedial Investigation for the Groundwater Operable Unit* (Ref. 3) indicate that current conditions within the surface water and sediments in Burgermeister Spring, while exhibiting above background concentrations of both nitrate and uranium, have not measurably affected the biological community that uses the drainage. Therefore, while sampling for both radiological and chemical constituents will be conducted at Burgermeister Spring as specified in this plan, routine monitoring of biological activity will not be incorporated.

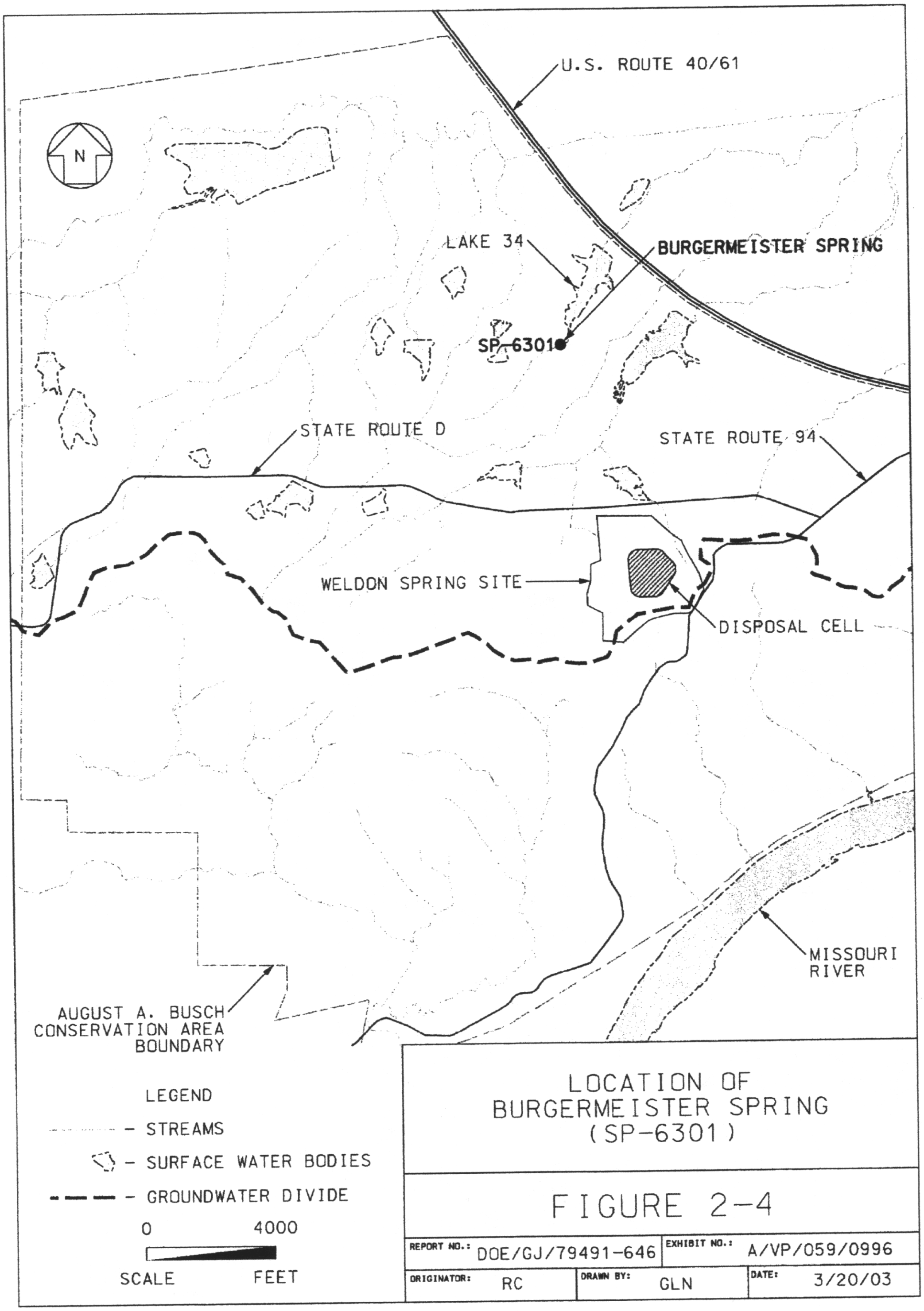

Figure 2-4 Location of Burgermeister Spring (SP-6301)

3. BASELINE MONITORING

In accordance with 40 CFR 264.97, baseline monitoring was conducted to obtain data that represents the quality of groundwater that has not been affected by leakage from the disposal cell. The intent was to establish a baseline data set that could be used in statistical comparisons with detection monitoring data, in accordance with regulatory requirements, to detect and characterize hazardous constituents in the uppermost aquifer that may be due to leakage from the disposal cell.

Review of the initial approach to baseline monitoring and the groundwater system beneath the chemical plant has indicated that in some cases an established baseline may not be appropriate for monitoring of the disposal cell at the Weldon Spring site. The shallow aquifer beneath the chemical plant has been impacted by previous operation of the former ordnance works and the uranium feeds material plant. This limits the reliability of results obtained using the statistical methods specified in the Subpart F regulations to evaluate long term monitoring data, which is discussed further in Section 4.7 and Appendix B. It is expected that groundwater conditions for the contaminants of concern for the Groundwater Operable Unit (nitrate, uranium, trichloroethylene, and nitroaromatic compounds) will improve over time due to source removal activities. Baseline values established for these contaminants using prior data may be biased high due to existing groundwater contamination or contamination resulting from contaminated soil remediation. Later comparisons to this baseline may mask trends in the groundwater.

3.1 Initial Baseline Monitoring

Baseline monitoring of locations MW-2032, MW-2045 through MW-2048, and SP-6301 was conducted throughout 1997 and early 1998, prior to waste placement activities. Four replicate samples were obtained from each location on a quarterly basis for approximately one year (i.e., five separate sampling events resulting in twenty individual samples per well). The initial baseline data indicated a large degree of temporal and spatial variability in water quality at the monitoring locations, as evidenced by the wide range of mean concentrations among monitoring locations and the high standard deviations calculated for many of the parameters. This variability is due to several contributing factors, such as the heterogeneity of the naturally occurring geochemistry, the variations in historical contaminant distribution throughout the site, and the unpredictable flow patterns in the fractured bedrock environment. Thus, the baseline conditions represented by the data were actually an indication of the groundwater quality at a particular location over a particular time period, and not a definitive characterization of background as intended by the Subpart F regulations.

Baseline monitoring of wells MW-2051 and MW-2055 began in 2001 and 2002, respectively. Samples from these wells are considered to be representative of water quality not impacted by the disposal cell since previous groundwater and leachate monitoring have indicated no reason to suspect leakage from the cell. Elements of the baseline sampling at these two wells have been similar to those listed above for the original six locations, except that the sampling events have consisted of a single sample (i.e., no replicates other than for QC purposes).

3.2 Previous Leachate Monitoring Evaluation

Regulations contained in 40 CFR 264.301 require leachate to be monitored during the active operation and post-closure period of a hazardous waste landfill. Although not specifically addressed by groundwater monitoring regulations, leachate monitoring is discussed in this plan because of the need to correlate the two programs to effectively monitor the potential migration of contaminants from the disposal cell.

Leachate production and analytical data have been collected routinely since waste placement activities began, in accordance with the *Disposal Cell Leachate Monitoring Plan* (Ref. 5) and the *Long-Term Stewardship Plan for the Weldon Spring, Missouri, Site* (Ref. 6). Samples were collected at least quarterly and analyzed for the entire list of parameters shown in Table 3-1. A summary of the average and maximum concentrations of analytical constituents detected in the leachate since the sump was completed (2000) is also presented in Table 3-1.

Table 3-1 Leachate Monitoring Data (10/18/00 to 5/8/02)

Parameter	Units	Concentration in Leachate (10-18-2000 to 5-8-2002)	
		Average	Maximum
Chloride(b)	(mg/l)	30.40	38.80
Fluoride(b)	(mg/l)	0.24	0.29
Nitrate-N(b)	(mg/l)	0.56	3.10
Sulfate(b)	(mg/l)	94.63	163.00
Aluminum	(µg/l)	33.12	70.50
Antimony	(µg/l)	ND	ND
Arsenic(b)	(µg/l)	3.73	9.36
Barium(b)	(µg/l)	606.88	832.00
Beryllium	(µg/l)	0.41	0.92
Cadmium	(µg/l)	ND	ND
Calcium	(mg/l)	176.25	198.00
Chromium(b)	(µg/l)	ND	ND
Cobalt(b)	(µg/l)	17.23	25.90
Copper	(µg/l)	3.48	9.90
Iron(b)	(µg/l)	12,083.00	22,100.00
Lead(b)	(µg/l)	ND	ND
Lithium	(µg/l)	7.99	13.20
Magnesium	(mg/l)	52.41	55.70
Manganese(b)	(µg/l)	5,396.00	9,970.00
Mercury	(µg/l)	ND	ND
Molybdenum	(µg/l)	5.82	7.75
Nickel(b)	(µg/l)	9.71	14.70
Potassium	(mg/l)	5.40	6.29

Table 3-2 Leachate Monitoring Data (10/18/00 to 5/8/02) (Continued)

Parameter	Units	Concentration in Leachate (10-18-2000 to 5-8-2002)	
		Average	Maximum
Selenium[b]	(μg/l)	1.24	3.95
Silver	(μg/l)	ND	ND
Sodium	(mg/l)	69.49	77.10
Thallium[b]	(μg/l)	3.45	10.60
Vanadium	(μg/l)	0.99	2.00
Zinc	(μg/l)	22.76	40.90
C.O.D.[b]	(mg/l)	28.60	35.00
Cyanide	(μg/l)	2.91	6.10
T.D.S.[b]	(mg/l)	867.20	970.00
T.O.C.[b]	(mg/l)	9.42	10.50
1,3,5-TNB[b]	(μg/l)	ND	ND
1,3-DNB[b]	(μg/l)	ND	ND
2,4,6-TNT[b]	(μg/l)	ND	ND
2,4-DNT[b]	(μg/l)	ND	ND
2,6-DNT[b]	(μg/l)	ND	ND
Nitrobenzene[b]	(μg/l)	ND	ND
Gross alpha	(pCi/l)	66.44	180.00
Gross beta	(pCi/l)	28.56	59.60
Ra-226[b]	(pCi/l)	0.32	0.68
Ra-228[b]	(pCi/l)	0.60	1.37
Th-228[b]	(pCi/l)	0.10	0.34
Th-230[b]	(pCi/l)	0.23	0.36
Th-232[b]	(pCi/l)	0.09	0.25
Total Uranium[b]	(pCi/l)	75.54	278.00
Pesticides	(μg/l)	ND[a]	0.26
PCBs[b]	(μg/l)	ND	ND
PAHs[b]	(μg/l)	ND	ND
VOCs	(μg/l)	ND[a]	5.20

Notes:

ND = non-detect

[a] All data were reported as non-detect, except for 3 or 4 isolated detections of individual compounds.

[b] These parameters are retained for leachate analysis as of the date of this plan.

3.3 Evaluation of Baseline Data

The original disposal cell monitoring plan specified that groundwater and surface water samples obtained under the plan be analyzed for all constituents presented in Table 3-2. This comprehensive list included general water quality indicator parameters (e.g., pH, temperature, total organic carbon, etc.), chemical and radiological contaminants, and naturally occurring constituents. The list included many parameters in addition to those that would be considered "hazardous constituents" under 40 CFR 264.93, and provided the basis for a thorough assessment of groundwater quality in the vicinity of the cell.

It was anticipated that the original list of analytical parameters would be evaluated periodically and modified as necessary to eliminate constituents that could provide no conclusive information regarding the presence of hazardous constituents due to a potential breach in the cell liner system. The first such modification was instituted in December 1999, after the initial baseline data had been evaluated and the detection monitoring program had begun (Ref. 7). Several parameters were eliminated from the list due to the lack of measurable detections in either the groundwater or the leachate, or because they were naturally occurring parameters that were not site contaminants of concern (see footnote "a" on Table 3-1).

Table 3-3 Constituents Monitored in Groundwater and Surface Water

General Indicator Parameters	Contaminants				
	Metals	Nitroaromatic Compounds	Radiological	Inorganic Ions	Other
pH[b] **Temperature**[b] **Specific Conductance**[b] **COD**[b] Cyanide[c] **TDS**[b] **TOC**[b] TOX[c]	Aluminum[c] Antimony[c] **Arsenic**[b] **Barium**[b] Beryllium[a] Cadmium[a] Calcium[a] **Chromium**[b] **Cobalt**[b] Copper[c] **Iron**[a][b] **Lead**[b] Lithium[c] Magnesium[c] **Manganese**[a][b] Mercury[a] Molybdenum[c] **Nickel**[b] Potassium[a] **Selenium**[b] Silver[c] Sodium[a] **Thallium**[a][b] Vanadium[c] Zinc[c]	**1,3,5-TNB**[b] **1,3-DNB**[b] **2,4,6-TNT**[b] **2,4-DNT**[b] **2,6-DNT**[b] **Nitrobenzene**[a][b]	**Radium-226**[b] **Radium-228**[b] **Thorium, Isotopic**[b] **Uranium, Total**[b]	**Chloride**[b] **Fluoride**[b] **Nitrate-N**[b] **Sulfate**[b]	**PCBs**[a][b] **PAHs**[a][b] VOCs[a] Pesticides[c]

COD Chemical Oxygen Demand
TDS Total Dissolved Solids
TOC Total Organic Carbon
VOCs Volatile Organic Compounds
TOX Total Organic Halogen

PCBs Polychlorinated Biphenyls: Aroclor 1248, 1254, 1260
PAHs Polyaromatic Hydrocarbons: benz(a)anthracene, benzo(b)fluorancene, benzo(k)fluorancene, benzo(a)pyrene, chrysene, indeno(1,2,3-cd)pyrene

[a] These parameters were deleted from the list in December 1999 because either they had not been detected previously in any measurable quantities or they were naturally occurring parameters that were not contaminants of concern (Ref. 7).
[b] These parameters are retained or reinstated for groundwater and surface water analysis as of the date of this plan.
[c] These parameters are eliminated as of the date of this plan.

3.3.1 Identification of Long-Term Monitoring Parameters

This revision further modifies the list of groundwater monitoring parameters based on a review of the Chemical Plant and Quarry Bulk Waste Operable Units contaminants of concern, materials known to be present in the disposal cell waste, and leachate analytical data. The following contaminants of concern were identified in wastes from the chemical plant and/or the quarry bulk waste: arsenic, chromium, lead, nickel, selenium, thallium, nitroaromatic compounds (specifically 2,4,6-DNT), radium, thorium, uranium, polychlorinated biphenyls (PCBs), and polyaromatic hydrocarbons (PAHs) (Refs. 1 and 8). In addition, barium, manganese, and selenium were determined to be present in the water treatment processing wastes during the remediation of contaminated surface water. As leachate analytical data have become available, the following constituents have been identified as being present at relatively higher concentrations in the leachate than in the underlying groundwater: arsenic, barium, cobalt, iron, manganese, uranium, and COD. These parameters are important to the cell monitoring network because a breach of the cell liner system could result in detectable increases in the levels of these constituents in the groundwater.

Since the above contaminants are known to be present in the disposal cell waste, it is possible that they may become constituents in the cell leachate and, if there is a breach in the system, eventually be detected in the underlying groundwater. Thus, the above contaminants are identified as monitoring parameters for this program.

3.3.2 Identification of Signature Parameters

Detection monitoring data obtained from the cell well network from 1998 through 2001 were evaluated using several of the suggested statistical methods in an attempt to identify statistically significant evidence of contamination due to the disposal cell. Results of these evaluations, which are summarized in Appendix B, demonstrate the uncertainties associated with applying the prescribed methods to data from an aquifer with preexisting contamination and where a high degree of spatial variation in contaminant distribution exists among the monitoring wells. Each type of evaluation resulted in numerous "false positive" statistical failures that, rather than providing reliable and conclusive evidence of cell leakage, were attributable to fluctuations in preexisting groundwater contamination.

The list of monitoring parameters in Table 3-2 includes indicator parameters and waste constituents that for an uncontaminated aquifer would provide a reliable indication of the presence of hazardous constituents in groundwater due to leakage from the disposal cell. However, most of these parameters are already present in the groundwater at higher levels than in the leachate, either naturally or due to historical contamination, or are not present in either the groundwater or the leachate at concentrations above the detection limit. Thus, most of the parameters on this list are not able to provide conclusive evidence of cell leakage since impacts from the leachate would not cause detectable changes in the underlying groundwater.

The most reliable means of detecting potential impacts due to leakage of the disposal cell is to focus on parameters that exist at significantly higher concentrations in the leachate than in the groundwater. An increasing trend in these parameters in the groundwater would be detectable and, most likely, attributable to cell leachate since all other sources have been remediated.

To this end, the following constituents have been identified as "signature parameters" for the disposal cell detection monitoring program: barium, uranium, iron, and manganese. All four of these parameters have been detected at concentrations at least an order of magnitude higher in the leachate (Table 3-1) than in the underlying groundwater or Burgermeister Spring (with the exception of uranium), which enhances the reliability of any conclusions that are drawn based on fluctuations in groundwater constituents. Increasing trends of these four parameters in the groundwater will be considered a signature of cell leachate that has migrated to the underlying aquifer and additional actions will be taken as described in Section 4.7. also, these four parameters are naturally occurring and with the exception of uranium should not change via attenuation overtime. Uranium, a contaminant of concern for the Groundwater Operable Unit, is expected to attenuate with time where uranium impact occurs. However, the activity measured in the disposal cell monitoring wells is similar to background and likely will not change substantially over time. It is anticipated that the list of signature parameters may be modified, as necessary, based on future changes in leachate and/or groundwater concentrations.

It should be noted that the uranium concentrations in Burgermeister Spring can be similar or higher than those exhibited in the leachate. This location is impacted by not only contaminated groundwater originating from the Raffinate Pit area, but also residual contamination that is present in the losing stream segment that extends from the Ash Pond area of the site to Burgermeister Spring. Increasing trends in uranium should not be used as the only indicator of possible leakage from the disposal cell.

3.4 Statistical Analysis of Data

3.4.1 Distribution of Data

The data for the signature parameters at the cell wells locations were examined to determine whether the data is normal or log-normal (Appendix B). The data shows a stronger evidence of log-normality than normality. However, to demonstrate that there is little difference in the method used to calculate the baseline tolerance limits, values were calculated for the signature parameters at three of the locations using six methods. The methods used were: EPA guidance suggested method on normal and log-normal data, tolerance limits on normal and log-normal data, and the mean plus 3 standard deviations on normal and log-normal data. All of the data from each location was used in this evaluation. The values calculated using the six methods yielded similar values for each of the signature parameters. Based on the evaluation (Appendix B), it is recommended to maintain the existing methodology of calculating baseline tolerance limits for the signature parameters and assume the data is distributed normally. Every 5 years, likely in conjunction with the CERCLA five-year reviews, the distribution of the data will be reevaluated.

3.4.2 Revised Baseline Tolerance Limits

Tolerance limits for signature parameters have been calculated using the dataset from 1997 through 2002, using 95% confidence and 95% coverage, based on the assumption that the data are normally distributed (Table 3-3). In the case of the newer wells (MW-2051 and MW-2055), the available data used is fairly small: however the tolerance limits for these wells are representative of groundwater conditions at these locations. Every 5 years, likely in conjunction with the CERCLA five-year reviews, the baseline tolerance limits will be recalculated.

Table 3-3 Baseline Tolerance Limits for Signature Parameters in Groundwater and Surface Water

Location	Signature Parameter			
	Barium (μg/l)	Iron (μg/l)	Manganese (μg/l)	Uranium (pCi/l)
MW-2032	377	1,125	57	6.4
MW-2046	277	1,578	187	1.8
MW-2047	471	1,485	171	2.7
MW-2051	285	2,896	265	4.5
MW-2055	98	10,579	179	7.5
SP-6301	180	2,608	88	159

In calculating these values, results reported as non-detect (ND) or less than the detection limit (DL) were assigned a value of one-half the DL. Estimated values less than the detection limit, when reported, were used rather than one-half the DL.

In accordance with the U. S. EPA guidance on *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (Ref. 10), the following formula was used to calculate baseline tolerance limits (BTLs):

$$BTL = x + k(s)$$

where: x = arithmetic mean of the baseline data
s = standard deviation of the baseline data
k = one-sided normal tolerance factor, based on number of values in the data set

The tolerance limits for each location using data collected through December 2002 is included in Appendix B. One-sided tolerance factors can be found in Table 5 - Appendix B of the EPA guidance (Ref. 10) and are also included in Appendix B.

4. DETECTION MONITORING PROGRAM

The goal of the detection monitoring program is to be able to detect releases of hazardous constituents from the disposal cell to the underlying aquifer. Detection monitoring is conducted in accordance with 40 CFR 264.98 throughout the life of the disposal cell to allow for the detection of hazardous constituents that may be migrating from the disposal cell.

The detection monitoring program, which began at this site in June 1998, has evolved since its inception as additional groundwater and leachate data have been obtained and evaluated in light of the relevant regulatory requirements. Resulting modifications to the plan have been incorporated through correspondence (Ref. 7 and 11), annual revisions to the site *Environmental Monitoring Plan* (Ref. 4), and this revision of the *Weldon Spring Site Disposal Cell Groundwater Monitoring Plan*.

4.1 Sampling Locations

Samples will be collected from monitoring wells MW-2032, MW-2046, MW-2047, MW-2051, and MW-2055. Samples will also be collected from Burgermeister Spring (SP-6301).

4.2 Parameters

Samples collected from the monitoring wells and Burgermeister Spring will be analyzed for the list of parameters given in Table 4-1. Quality control sampling is discussed in Section 7.

Table 4-1 Detection Monitoring Parameter List for Groundwater and Surface Water

Radiological	Inorganic Ions	Metals	Nitroaromatic Compounds	Other	General Indicator Parameters
Radium-226 Radium-228 Thorium, Isotopic Uranium, Total *	Chloride Fluoride Nitrate (as N) Sulfate	Arsenic Barium * Chromium Cobalt Iron * Lead Manganese * Nickel Selenium Thallium	1,3,5-TNB 1,3-DNB 2,4,6-TNT 2,4-DNT 2,6-DNT Nitrobenzene	PCBs PAHs	pH Temperature Specific Conductance COD TDS TOC Turbidity

* Signature parameters (see Section 3.3.2)

4.3 Sampling Frequency

Each monitoring well and Burgermeister Spring will be sampled on a semiannual frequency. Samples will be collected during June and December of each year. This sampling frequency will provide an adequate dataset for use in developing a moving baseline for each location (Section 3.3), and assists in eliminating the spatial and temporal variability seen in earlier datasets. Burgermeister Spring will be sampled during baseflow conditions, which is the stage of spring discharge when the water is least influenced by active surface runoff. Samples will be collected no sooner than 1 week following the end of a precipitation event of sufficient intensity to result in surface runoff. The flow rate of the spring will be estimated and recorded at each sampling event.

The original disposal cell groundwater monitoring plan called for collecting four replicates at each monitoring location on a semi-annual basis. In 1999, the monitoring frequency was reduced to a single sample collected semi-annually from each location since independent replicates could not be collected within a short time period because of slow groundwater flow rates.

4.4 Groundwater Elevation Measurements

Groundwater elevations will be measured semiannually at each of the disposal cell monitoring well locations prior to each sampling event. Results for 1997 through 2002 are presented in Figure 4-1. Groundwater elevations have remained relatively constant since the wells were installed. Groundwater flow rates and flow directions will be evaluated annually. A presentation of the potentiometric surface and determination of the flow rates and directions for 1998 through 2002 are presented in Appendix C.

4.5 Precipitation Data

To support leachate monitoring activities at a regulated unit, Missouri Hazardous Waste regulations require the collection of local precipitation data. An onsite meteorological station was used to monitor daily and hourly precipitation until December 2001, as described in the *Environmental Monitoring Plan* (Ref. 4). More recent and future regional precipitation data (e.g., from the Spirit of St. Louis Airport in Chesterfield, MO) is obtained as needed through the National Oceanographic and Atmospheric Administration at the following internet address:

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4.6 Leachate Monitoring

Regulations contained in 40 CFR 264.301 require leachate to be monitored during the active operation and post-closure period of a hazardous waste landfill. Although not specifically addressed by groundwater monitoring regulations, leachate monitoring is discussed in this plan because of the need to correlate the two programs to effectively monitor the potential migration of contaminants from the disposal cell.

This plan revision modifies the leachate monitoring parameters to be the same as the list of parameters monitored in the groundwater. The leachate will continue to be monitored

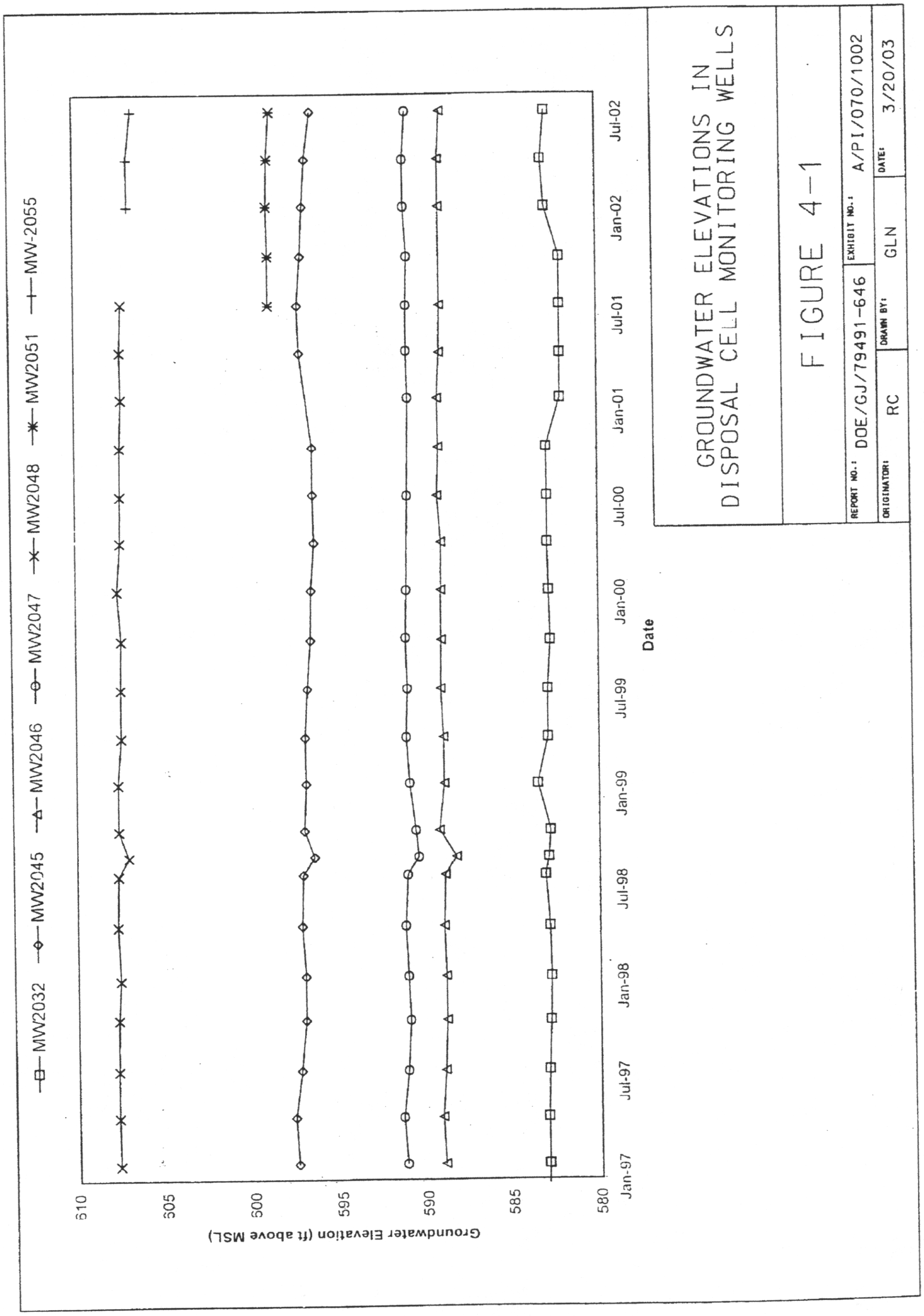


Figure 4-1 Groundwater Elevations in Disposal Cell Monitoring Wells

semiannually for the parameters outlined in Table 4-1. Samples will be collected in June and December of each year.

4.7 Detection Monitoring Data Review

4.7.1 Signature Parameters

Under the detection monitoring program, data for only the signature parameters from each monitoring event will be compared to baseline tolerance limits (Table 3-3) to track general changes in groundwater quality and determine whether statistically significant increases in these parameters has occurred. Previously, all the parameters were evaluated against the appropriate baseline tolerance limits and exceedances were attributable to variations in existing groundwater quality, interference from turbid samples, leaching of metals (chromium, nickel, cobalt, and molybdenum) from stainless steel (Type 316) well materials, sample preservation or analytical error, or inherent uncertainties in data that are less than five times greater than the detection limit.

For signature parameters (barium, iron, manganese, and uranium) that are determined to exceed the baseline tolerance limits, the following actions will be taken:

- The location will be resampled to confirm the exceedence. If the exceedence is not confirmed, detection monitoring will continue and no further action is necessary.
- If resampling results confirm the exceedence, a thorough evaluation will be performed to determine whether it is due to leakage from the disposal cell. This evaluation may include an assessment of groundwater gradients, review of leachate production and analytical data, review of sitewide monitoring data, and additional sampling. If it is shown that the upward trend is not due to leakage from the cell, a demonstration report will be prepared in accordance with the substantive requirements of 40 CFR 264.98, and detection monitoring will continue.

4.7.2 Other Parameters

The data from the remainder of the parameters will be reviewed to evaluate the general groundwater quality in the vicinity of the disposal cell and to determine if changes are occurring in the groundwater system. Data will be compared to the 3 most recent years of data to determine if statistically significant increases or trends in concentrations are present. A "moving average" approach, as discussed in the October 11, 1989 Federal Register (Ref, 9), is used to better reflect naturally occurring changes in site hydrogeology, minimize temporal variations, and account for the natural attenuation of contaminants in the shallow aquifer. Data will be considered statistically significant if it is greater than the arithmetic mean plus 3 times the standard deviation for each location.

Data that are determined to be statistically significant will be evaluated as follows:

- The location will be resampled to confirm the exceedence. If the exceedence is not confirmed, no further action is necessary.

- If results of the resampling confirm the exceedence, the data will be compared to the leachate data. If the leachate data do not indicate that the exceedence could be the result of leakage from the cell (parameter is not elevated in the leachate), an assessment of the analytical data and review of sitewide monitoring data will be performed. If the exceeding parameter is a contaminant of concern for the Groundwater Operable Unit (nitrate, nitroaromatic compounds, or trichloroethylene), this information will be evaluated under the monitoring program for the Groundwater Operable Unit at the chemical plant.

- If results of the resampling confirm the exceedence, the data will be compared to the leachate data. If the leachate data indicate that the exceedence could be the result of leakage from the cell (parameter is also elevated in the leachate), the entire disposal cell monitoring network will be sampled for the full list of parameters shown in Table 3-2. A revised monitoring plan, which incorporates the results of the enhanced sampling and outlines the specific details of the compliance monitoring program (Section 5), and an engineering feasibility plan for corrective action will be prepared in accordance with substantive requirements of 40 CFR 264.99.

4.7.3 Leachate

Analytical data from the leachate will be compared to the analytical data from the monitoring well network to determine the adequacy of the signature parameters for this plan. If the composition of the leachate changes substantially, a parameter may be included or removed from the signature parameter list. If the concentration of a parameter decreases so that it is not distinguishable from concentrations (similar in concentrations) in groundwater, that parameter will be removed from the signature parameter list. Conversely, if the concentration of a parameter increases to a level that distinguishable from the concentrations in groundwater (order of magnitude greater), it would warrant its inclusion in the signature parameter list. This evaluation will be performed annually.

4.8 Detection Monitoring Reporting

4.8.1 Annual Reporting

Disposal cell monitoring data are reported annually in the *Weldon Spring Site Environmental Reports* (Refs. 12, 13, 14, and 15). Data to be reported includes all detectable analytical results, as well as groundwater flow rate and direction. However, since only analytical results were reported prior to 2002, groundwater flow rates and direction for the years 1998 through 2002 are included in Appendix C of this plan.

Confirmed exceedances of signature parameters are investigated further by evaluating water levels and precipitation data and reviewing historical analytical and field monitoring data to determine the likely cause and contributing factors. A summary of the exceedances and results of the investigations are reported both in the annual site environmental report and in the quarterly *Federal Facilities Agreement (FFA) Report.*

4.8.2 Demonstration Reporting

A demonstration report will be prepared if it is shown that an upward trend in a signature parameter is not due to leakage from the cell. This report will document the evaluation used to derive the conclusion that leakage has not occurred from the disposal cell. This evaluation may include an assessment of data quality, groundwater gradients, review of leachate production and analytical data, review of sitewide monitoring data, and additional sampling.

5. COMPLIANCE MONITORING AND CORRECTIVE ACTION PROGRAMS

If it is determined that leakage from the cell has resulted in deterioration of the groundwater at the chemical plant, a review of the remedy will be necessary. This is based on the condition that the remedy is not behaving as expected and may no longer be protective of human health and the environment. Modifications or actions would be documented under CERCLA and would be consistent with 40 CFR 264.100, if appropriate. Identification of applicable or relevant and appropriate regulations (ARARs) would be make at that time and my include groundwater protection standards as outlined in 40 CFR 264.92, if appropriate. At that time, a modification of this program would be documented in collaboration with the U.S. Environmental Protection Agency – Region VII and the Missouri Department of Natural Resources. The monitoring program will continue as prescribed in Section 4 and the nature and extent of the release will be investigated.

6. QUALITY CONTROL

6.1 Sampling and Analysis Procedures

The general groundwater monitoring requirements in 40 CFR 264.97 specify that the monitoring program for a regulated unit must incorporate consistent, reliable, appropriate, and accurate sampling and analysis procedures. The *Ground Water and Surface Water Sampling and Analysis Plan for GJO Projects* (Ref. 16) establishes the data quality requirements for all environmental data collected at the Weldon Spring Site, including data obtained in support of the disposal cell groundwater monitoring plan. Standard operating procedures (SOPs) have been developed and implemented to provide consistency in sample collection methodology and documentation of environmental activities. The appropriate sections of the *Sampling and Analysis Plan* identified below apply to all monitoring activities conducted under this plan.

6.1.1 Field Documentation

Water elevations, sample locations, water temperatures, and other physical parameters are recorded in the field. This information will be recorded and documented as provided in Section 4.3 of the *Sampling and Analysis Plan.*

6.1.2 Field Measurements and Equipment Calibration

Prior to sample collection, specific field parameters are measured. These include the physical parameters listed above and groundwater elevations. Procedures for obtaining these measurements and calibration of equipment are provided in Section 3.6 of the *Sampling and Analysis Plan.*

6.1.3 Sample Identification

All samples, including quality control samples, collected under this monitoring plan are identified with a unique sample identification number, according to Section 6.0 of the *Sampling and Analysis Plan.*

6.1.4 Sample Collection, Preparation, and Preservation

Procedures for collecting groundwater and spring samples are defined in Section 3.7 of the *Sampling and Analysis Plan.* All samples collected under this plan will be unfiltered. Table 7-1 lists the general sample preparation and preservation requirements for each parameter. All samples taken are collected in certified-clean plastic, clear glass, or amber glass bottles, as appropriate for analysis. Sample packaging and shipping conforms to Section 6.0 of the *Sampling and Analysis Plan.*

Table 6-1 Sample Preparation and Preservation Requirements

ANALYSIS	SAMPLE CONTAINER SIZE/TYPE	PRESERVATION	HOLDING TIME[a]	VOLUME REQUIRED (Minimum)	MS/MD OR DU VOLUME REQUIRED
Nitroaromatic Compounds	1-liter amber glass	4°C (ice)	7 days	1000 ml	3000 ml
Metals	1-liter plastic	HNO_3 - pH of <2	6 months (Hg: 28 days)	500 ml	1000 ml
Sulfate Fluoride Chloride TDS	1-liter plastic	4°C (ice)	28 days (TDS-7 days)	300 ml	1000 ml
Uranium, total Thorium, isotopic Radium-226 Radium-228	4-liter plastic cubit	HNO_3 - pH of <2	6 months	4 liters	12 liters
PCBs	1-liter amber glass	4°C (ice)	7 days	1000 ml	3000 ml
PAHs	1-liter amber glass	4°C (ice)	7 days	1000 ml	3000 ml
Nitrate (as N) TOC TOX COD	500-ml amber glass	H_2SO_4 - pH of <2	28 days	300 ml	1000 ml
VOCs	40-ml vial	4°C (ice) HCl - pH of <2	14 days	80 ml (2 vials)	160 ml (4 vials)

MS Matrix Spike; MD Matrix Spike Duplicate; DU Duplicate
HNO_3 – Nitric Acid; H_2SO_4 – Sulfuric Acid; HCl – Hydrochloric Acid
[a] Actual extraction/analysis holding times are variable. Samples should be shipped immediately after collection.

6.1.5 Chain-of-Custody

Chain-of-Custody forms are maintained for all environmental samples collected. The chain-of-custody process is detailed in Section 6.0 of the *Sampling and Analysis Plan.* This section also outlines specific instructions for ensuring that samples are not tampered with or altered prior to analysis.

6.1.6 Sampling Equipment Decontamination

All groundwater wells have dedicated bladder pumps and hoses. Other sampling equipment is decontaminated as necessary according to Section 7.0 of the *Sampling and Analysis Plan*.

6.1.7 Analytical Procedures

Analytical testing is conducted by either the GJO Analytical Chemistry Lab or by subcontracted laboratories (nitroaromatic compounds) that follow the EPA Contract Laboratory Program (CLP) requirements for metals and organic compounds, the EPA drinking water and radiochemical methodologies for other parameters, or alternate methods, as described in Section 5.0 of the *Sampling and Analysis Plan*.

Detection limits are specified in contracts established with the laboratories. In general, these detection limits follow CLP protocol and standard analytical methodology. Table 7-2 provides the detection limits and analytical methods used for the disposal cell groundwater monitoring program.

Table 6-2 Specified Detection Limits and Analytical Methods

Analytical Parameter	Analytical Method	Required Detection Limit
WET CHEMISTRY PARAMETERS		
Total Organic Halides	SW-846 9020A	0.5 mg/l
Chemical Oxygen Demand	EPA 410	5.0 mg/l
Total Organic Carbon	EPA 415.1	0.1 mg/l
Total Dissolved Solids	EPA 160.2	1.0 mg/l
RADIOLOGICAL CONSTITUENTS		
Total Uranium	ASTM 5174-91 (Fluorimetry or KPA) or equivalent	1.0 pCi/l
Isotopic Thorium	ASTM, EPA, EML or equivalent	0.2 pCi/l (each isotope)
Radium-226	ASTM, EPA, EML or equivalent	1.0 pCi/l
Radium-228	ASTM, EPA, EML or equivalent	5.0 pCi/l
NITROAROMATIC COMPOUNDS		
2,4-DNT	USATHAMA or EPA 8330	0.030 µg/l
2,6-DNT	USATHAMA or EPA 8330	0.010 µg/l
2,4,6-TNT	USATHAMA or EPA 8330	0.030 µg/l
1,3,5-TNB	USATHAMA or EPA 8330	0.030 µg/l
1,3-DNB	USATHAMA or EPA 8330	0.090 µg/l
Nitrobenzene	USATHAMA or EPA 8330	0.030 µg/l
INORGANIC IONS		
Nitrate-N	EPA 300/340	0.10 mg/l
Sulfate	EPA 300/375	2.0 mg/l
Fluoride	EPA 300/375	0.1 mg/l
Chloride	EPA 300/375	0.25 mg/l
METALS		
All	Contract Lab Program	Instrument Detection Limits (IDLs)
ADDITIONAL CONSTITUENTS		
PAHs	SW846 8310	5.0 µg/l (each parameter)
PCBs	EPA 608 or SW846 8081a/8082	1.0 µg/l (each parameter)

6.2 Quality Control Samples

Quality control (QC) samples are collected to ensure consistent and accurate performance of sample collection and laboratory analysis activities. Section 4.0 of the *Sampling and Analysis Plan* defines the QC samples to be collected, the recommended collection frequency, and the collection procedures. Table 7-3 lists the types of quality control samples that will be collected under this plan and identifies their purpose in support of the monitoring program.

Table 6-3 Field Quality Control Sample Summary

QUALITY CONTROL SAMPLE TYPE	FREQUENCY	PURPOSE
Duplicate/Matrix Spike/Matrix Spike Duplicate	1 per 20 samples	Assess laboratory method variability.
Field Replicate	1 per 20 samples	Assess matrix variability.
Deionized Water Blank	1 per month	Assess quality of deionized water used to decontaminate water level meter.

6.3 Data Review

The *Sampling and Analysis Plan* (Section 5 and Appendix B) describes the verification, validation, and technical review process to which data obtained under this plan are subject. Analytical data obtained under this plan are maintained in the GJO SEEPro database. This database allows for data input, storage, and retrieval so that the statistical analyses required under this plan can be performed.

7. REFERENCES

1. U.S. Department of Energy. *Record of Decision for Remedial Action at the Chemical Plant Area of the Weldon Spring Site.* DOE/OR/21548-376. Oak Ridge Field Office. St. Charles, MO. September 1993.

2. MK-Environmental Services. *WSSRAP Disposal Cell Monitoring Well Program Installation Report*, Rev. 0. Technical Memorandum No. 3840TM-7220-0. Prepared for MK-Ferguson Group. February 1997.

3. Argonne National Laboratory. *Remedial Investigation for the Groundwater Operable Units at the Chemical Plant Area and the Ordnance Works Area, Weldon Spring, Missouri.* DOE/OR/21548-571. Prepared for the U.S. Department of Energy, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri. July 1997.

4. MK-Ferguson Company and Jacobs Engineering Group. *Environmental Monitoring Plan*, Rev. 9. DOE/OR/21548-424. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. December 2001.

5. *Disposal Cell Leachate Monitoring Plan.* Interoffice memorandum from J. Bennett to Distribution. June 22, 1998.

6. U.S Department of Energy. *Long-Term Stewardship Plan for the Weldon Spring, Missouri, Site*. GJO-2002-342-TAC. Grand Junction Office. Grand Junction, CO. August 9, 2002.

7. *Disposal Cell Detection Monitoring Status.* Letter from D. Steffen to S. McCracken, December 3, 1999.

8. U.S. Department of Energy. *Record of Decision for the Management of the Bulk Wastes at the Weldon Spring Quarry.* Weldon Spring, MO. September 1990.

9. U.S. Environmental Protection Agency. *Federal Register, Part II. 40 CFR Part 264, Statistical Methods for Evaluating Ground-Water Monitoring from Hazardous Waste Facilities, Final Rule.* October 11, 1989.

10. U.S. Environmental Protection Agency, Office of Solid Waste, Waste Management Division. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities - Interim Final Guidance.* EPA/530-SW-89-026. Washington, D.C. April 1989.

11. *Disposal Cell Detection Monitoring Status - Update.* Letter from D. Steffen to S. McCracken. December 21, 1999.

12. MK-Ferguson Company and Jacobs Engineering Group. *Weldon Spring Site Environmental Report for Calendar Year 1998.* Rev. 0. DOE/OR/21548-773. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. Weldon Spring, Missouri. July 1999..

13. MK-Ferguson Company and Jacobs Engineering Group. *Weldon Spring Site Environmental Report for Calendar Year 1999.* Rev. 0. DOE/OR/21548-845. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. Weldon Spring, Missouri. July 2000.

14. MK-Ferguson Company and Jacobs Engineering Group. *Weldon Spring Site Environmental Report for Calendar Year 2000.* Rev. 0. DOE/OR/21548-886. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. Weldon Spring, Missouri. July 2001.

15. MK-Ferguson Company and Jacobs Engineering Group. *Weldon Spring Site Environmental Report for Calendar Year 2001.* Rev. 0. DOE/OR/21548-917. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. Weldon Spring, Missouri. July 2002.

16. U.S. Department of Energy. *Ground Water and Surface Water Sampling and Analysis Plan for GJO Projects.* Rev. 6. GJO-2003-402-TAC/GJO-GWADM 19.1-1. Grand Junction Office, Grand Junction, Colorado. December 2002.

17. U.S Environmental Protection Agency, Office of Solid Waste. *RCRA Ground-Water Monitoring: Draft Technical Guidance.* EPA/530-R-93-001. Washington, D.C. November 1992

APPENDIX A

Monitoring Well Installation Logs

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER	MW-2032
SHEET 1 OF 2	
NORTH (Y):	1044508.74
EAST (X):	755016.39
TOC ELEVATION	637.48
GROUND ELEVATION	635.81
STICKUP	1.67
HYDR CONDUCTIVITY (cm/sec)	K= N/A

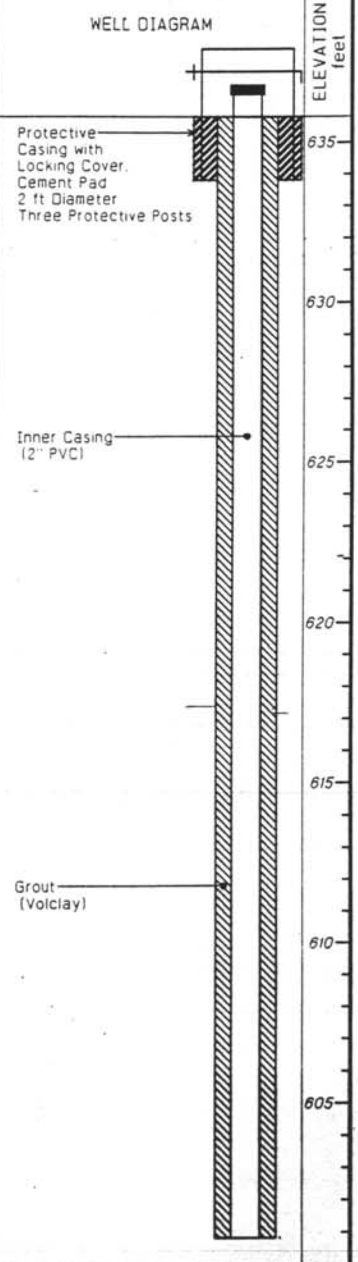
WELL STATUS/COMMENTS	ACTIVE
LOCATION	27'SW MW2023, 30' SE MW2024 (AEC)
DRILLING CONTRACTOR	HANIBAL TESTING LABS
DRILL RIG MAKE & MODEL	CME 55/75, NQ WIRELINE
HOLE SIZE & METHOD	7 5/16 "O.D. 4 1/4" I.D.
ANGLE FROM HORIZONTAL & BEARING	90
BOTTOM OF HOLE (TD)	60.0
DRILL FLUIDS & ADDITIVES	WATER
CASING TYPE, DEPTH, SIZE	2" PVC
BEDROCK	48.5
DATE START	08-11-1989
DATE FINISH	07-15-1989
WATER LEVELS & DATES	▽12-04-92 ▼05-31-91

DEPTH (FT.) FROM GROUND ELEV. TO

LITHOLOGY BY A.BENFER

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
0–5	SS-1	10/18"	7	ML	CLAYEY SILT, dark gray to brownish yellow, low plasticity, damp, medium stiff, MnOx & FeOx.	Qlv
5	ST-2	27/30"		CL	SILTY CLAY, brownish yellow, medium plastic, 20% sand, trace rounded gravel, moist, very stiff. Becomes mottled with light gray and MnOx at 9 feet. Light yellowish brown with caliche, very stiff with silt pockets at 12.5.	Qct
	SS-3	15/18"	10			
10	ST-4	25/30"				
	SS-5	16/18"	9			
15	ST-6	24/30"				
	SS-7	18/18"	14		SILTY CLAY, brownish yellow, medium plasticity, 10% sand, fine gravel, stringers of light gray and MnOx, damp, hard. ft.	
20	ST-8	30/30"				
	SS-9	18/18"	16	CH	SILTY CLAY, as above, highly plastic.	
25	ST-10	11/12"		ML CL	SILT to SILTY CLAY, light brownish gray, medium plasticity, moist, very stiff. Minor gravel, angular, up to 1.5 inches at 30 feet.	
	SS-11	18/18"	13	CH	CLAY, brownish yellow, highly plastic, moist, very stiff, contains 5% sand, 15% fine gravel and MnOx.	
30	ST-12	18/18"	34		Minor gravel, angular, up to 1.5 inches at 30 feet.	
	SS-13	13/18"	18			
35	SB-14	16/18"	33	ML		

WELL DIAGRAM



Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER MW-2032

SHEET 2 OF 2

NORTH (Y): 1044508.74

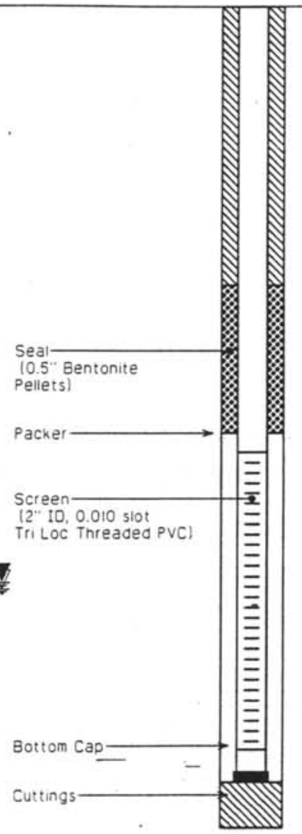
EAST (X): 755016.39

WELL STATUS/COMMENTS ACTIVE

LOCATION 27' SW MW2023, 30' SE MW2024 (AEC)

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	ELEVATION feet
		16/18"		ML	SILT, reddish yellow, low plasticity, abundant FeOx, minor gravel, very soft.	Qct	600
	SS-15	16/18"	24	GC	CLAYEY GRAVEL, yellowish red, angular white chert gravel, plastic, moist, dense, hard.	pPr	
40	SB-16	12/18"	39		Highly fractured and weathered chert and 25% clay, very moist at 40 feet. Stiff at 45 feet.		595
45	SS-17	18/18"	15				590
	NQ-1	7/54"	10	GC chrt	CHERT fragments, white, weathered, minor MnOx and FeOx.	MDksw	
50							585
	NQ-2	66/66"	64	lms	LIMESTONE, yellow, silty, moderately weathered, contains finely dissiminated oxidized pyrite. Chert, white, fresh.	MDkw	
55					LIMESTONE and CHERT, as above, 50% chert distributed throughout providing a breccia appearance. Chert, white to bluish to pinkish.		580
	NQ-3	18/18"	57				
60					Total depth 60.0 feet.		575
65							570
70							565
75							

WELL DIAGRAM



Sample Interval ☐ No Sample Taken ▽ minimum ▼ maximum ▼ average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

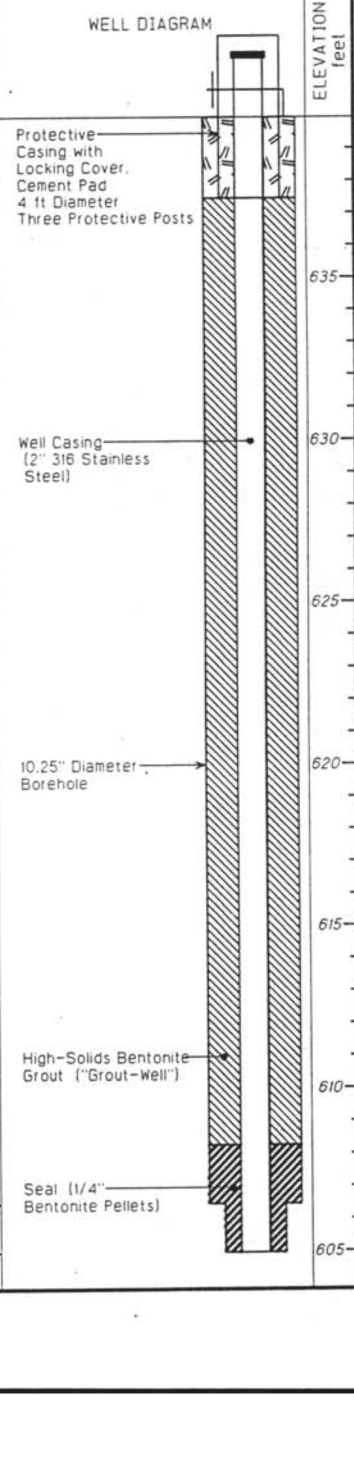
HOLE NUMBER	MW-2045 (C2)
SHEET 1 OF 2	
NORTH (Y):	1043883.98
EAST (X):	755615.24
TOC ELEVATION	641.82
GROUND ELEVATION	639.95
STICKUP	1.87
HYDR CONDUCTIVITY (cm/sec)	K= 1.44x10⁻³ (Packer Test)

WELL STATUS/COMMENTS: ACTIVE		LOCATION: Downgradient of Disposal Cell
DRILLING CONTRACTOR: GEOTECHNOLOGY INC.		DRILL RIG MAKE & MODEL: CME 750, HSA/NQWL CORE/SCHRAMM AIR ROT.
HOLE SIZE & METHOD: 10 1/4" HSA to 33.5' then 6" Air	ANGLE FROM HORIZONTAL & BEARING: 90	DEPTH (FT.) FROM GROUND ELEV. TO: BOTTOM OF HOLE (TD): 50.0
DRILL FLUIDS & ADDITIVES: WATER/AIR	CASING TYPE, DEPTH, SIZE: 2" 316 STAINLESS STEEL	BEDROCK: 33.5
DATE START: 10-15-1996	DATE FINISH: 11-1-1996	WATER LEVELS & DATES: ▽ ▼

LITHOLOGY BY P. PATCHIN/S. VINCENT

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
0	CME-1	42/42"		TS	0-.2' TOPSOIL, brownish gray with roots.	Qp
				CL ML	.2 - 1.0' SILTY CLAY/CLAYEY SILT, mottled yellowish brown (10YR 5/6) with minor brownish yellow (10YR 6/8), non-plastic to low plasticity, slightly moist, very stiff (pp=3.0), roots.	Qrx
				CH	1.0 - 1.9' SILTY CLAY/CLAYEY SILT color as above, nonplastic, dry to damp, hard (pp=4.0+), minor MnOx stain, roots, FeOx blebs.	Qfv
	CME-2	60/60"			1.9 - 5.8' SILTY CLAY, mottled yellowish brown (10YR 5/8), and minor grayish brown (10YR 5/2), medium to high plasticity, slightly moist, very stiff (pp=2.75), minor (<5%) angular chert gravel to 1/2".	Qfv
5				CL	5.8 - 18.0' SILTY, SANDY CLAY with GRAVEL, yellowish brown (10YR 5/8) with minor light brownish gray leaching along fractures, low plasticity, dry, hard (pp=4.5+), very sandy (v.fine) with approx. 5-10% gravel (v.fine to 2"+) which is rounded (igneous) and angular (limestone and chert), very fractured with abundant MnOx along fracts., gray granular CaCO3 in thin lenses at 15.0' and 17.5'.	Qct
	CME-3	60/60"				
10						
	CME-4	60/60"				
15						
	CME-5	48/48"		CL CH	18.0 - 20.0' CLAY, strong brown (7.5 YR 4/6) with minor reddish mottling, medium to high plasticity, slightly moist hard (pp=4.5+), little to no sand or gravel, grayish silty pockets (occasional), abund. FeOx nodules, abund. MnOx on fractures.	Qct
20				CL	20.0 - 22.2' CLAY, slightly silty, mottled dark red (2.5YR 4/6) and minor light brownish gray (2.5YR 6/2), low plasticity, damp to slightly moist, very stiff (pp=2.25-3.25), very crumbly and blocky structure, waxy, with silty pockets from 21.0 - 22.2'.	pPr
	SS-6	11/11"	+50	GC	22.2' CLAYEY GRAVEL, color as above but with weathered chert gravel (60%-70%) to >2", very angular and "shattered". Chert gravel is generally white (10YR 8/1), hard to very hard, moderately weathered. Interstitial clay is as above, damp to slightly moist.	pPr
25				CL GC	GRAVELLY CLAY/CLAYEY GRAVEL, (alternating broken chert gravel and clay with gravel), clays is strong brown (10YR 4/6), med. to high plasticity, slightly moist, very stiff, with minor fine chert gravel as above.	pPr
	SS-7	12/24"	43			
30						
					Top of Bedrock @ 33.5 ft.	Mbksw
35	RUN-1	78/120"	30	lms chrt	33.5 - 43.7' ARGILLACOUS LIMESTONE AND CHERT, interbedded and brecciated (approximately 60/40). Limestone is grayish orange (10YR 7/4) to pale yellowish brown (10YR 6/2), mottled with	Mbksw

WELL DIAGRAM



▮ Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

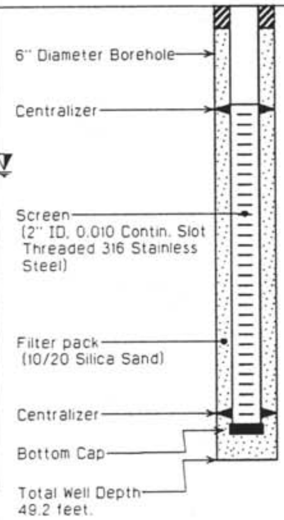
HOLE NUMBER	MW-2045 (C2)
SHEET 2 OF 2	
NORTH (Y):	1043883.98
EAST (X):	755615.24

WELL STATUS/COMMENTS: ACTIVE

LOCATION: Downgradient of Disposal Cell

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery (0–100)	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	ELEVATION feet
						lms chrt	very light gray (N8) chert. Limestone is fine to medium-grained, very argillaceous, thin-bedded, mod. hard, mod. weathered with vugs pinpoint to 1", abundant FeOx staining and closely fractured. Minor stylolites and fossils. Chert is brecciated and interbedded with limestone and as nodules (to 5"), very hard, fossiliferous with MnOx staining on micro-fractures and in matrix. "Strongly Weathered Burlington-Keokuk Limestone" from 34.0-39 ft. then "Weathered Burlington-Keokuk Limestone" to total depth.	MDksw	
40						lms chrt		MDkw	600
		RUN-2	70/72"	70			43.7 - 49.1' ARGILLACEOUS LIMESTONE AND CHERT, as above but increased clay content and very fine grained (micritic), less chert (approx. 30%), moderate to high porosity.		
45							Kp = CONSTANT HEAD SINGLE PACKER PRESSURE TESTS 37.3 to 44.0 ft. K=1.4E-3 cm/sec; 39.6 to 50.0 ft. k=8.8E-4 cm/sec		595
						chrt	49.1 - 50.0' CHERT, mottled very light gray (N8) and brownish gray (5YR 4/1), very hard, slightly weathered, closely fractured with heavy FeOx staining on fracture surfaces.		
50							Total cored depth 50.0 feet. Switched to 6" air rotary and reamed hole to 49.2'.		590
55							Note: Soil and rock color are indexed on the Muncell soil color chart.		585
60									580
65									575
70									570
75									565

WELL DIAGRAM



Sample Interval   No Sample Taken   minimum   maximum   average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

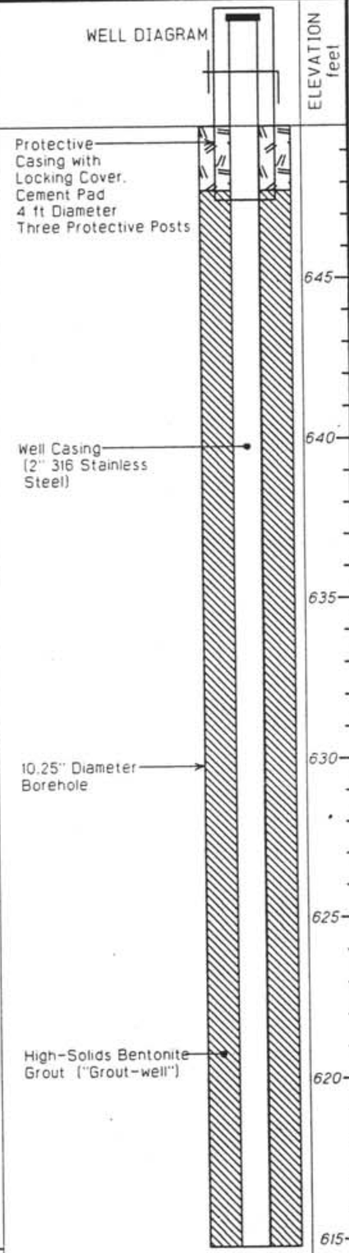
HOLE NUMBER	MW-2046 (C3)
SHEET	1 OF 2
NORTH (Y):	1044158.17
EAST (X):	755046.76
TOC ELEVATION	653.54
GROUND ELEVATION	649.77
STICKUP	3.77
HYDR CONDUCTIVITY (cm/sec)	$K = 4.85 \times 10^{-6}$ (Packer Test)

WELL STATUS/COMMENTS	ACTIVE
LOCATION	Upgradient of Disposal Cell
DRILLING CONTRACTOR	GEOTECHNOLOGY
DRILL RIG MAKE & MODEL	CME 750, HSA/NQWL CORE/SCHRAMM AIR ROT.
HOLE SIZE & METHOD	10 1/4" HSA to 51.8' then 6" Air
ANGLE FROM HORIZONTAL & BEARING	90
DEPTH (FT.) FROM GROUND ELEV. TO: BOTTOM OF HOLE (TD)	74.0
DRILL FLUIDS & ADDITIVES	WATER/AIR
CASING TYPE, DEPTH, SIZE	2" 316 STAINLESS STEEL
BEDROCK	51.8
DATE START	11-5-1996
DATE FINISH	11-15-1996
WATER LEVELS & DATES	
LITHOLOGY BY	SEAN VINCENT/PAUL PATCHIN

SAMPLE/RUN Number	PERCENT Recovery	N# or RQD
SS-1	18/24"	19
SS-2	19/24"	18
SS-3	24/24"	12
SS-4	24/24"	17
SS-5	24/24"	20
SS-6	24/24"	25
SS-7	24/24"	19
SS-8	24/24"	27
SS-9	24/24"	32
SS-10	24/24"	32
SS-11	24/24"	27
SS-12	24/24"	28
SS-13	24/24"	28
SS-14	24/24"	29

SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
Fill	0 - 1.5' FILL, gravel drill pad (3" minus rock)	Fill
CL ML	SILTY CLAY/CLAYEY SILT, yellowish brown (10YR 5/6), low plasticity, slightly moist, very stiff (pp=3.0).	Qrx
CH	2.1 - 13.8' CLAY, mottled yellowish brown (10YR 5/4) and grayish brown (10YR 5/2), medium to high plasticity, slightly moist, very stiff (pp=2.75).	Qfv
	CLAY, as above, black MnOx staining is common.	Qfv
	CLAY, as above, very stiff (pp=3.5).	Qfv
CL CH	13.8 - 32.0' SILTY CLAY, yellowish brown (10YR 5/8) with light greenish gray (5GY 7/1) along fractures, medium to high plasticity, approx. 5% angular chert gravel to 1" with trace subrounded to rounded igneous gravel, hard (pp=4.5), grading to higher silt and fine sand content with depth	Qct
CL	SILTY CLAY, as above, medium plasticity, waxy appearance, hard (pp=4.0).	Qct
	32.0 - 34.0' SILTY CLAY, as above but with red (2.5YR 5/6) color and includes occasional subangular to angular chert fragments.	Qct
	34.0 - 37.5' SILTY CLAY, as above but color is yellowish brown (10YR 5/6) with light gray (10YR 7/2) silt in fractures, occasional FeOx nodules	Qct

WELL DIAGRAM



Sample Interval   No Sample Taken   minimum   maximum   average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER: MW-2046 (C3)

SHEET 2 OF 2

NORTH (Y): 1044158.17

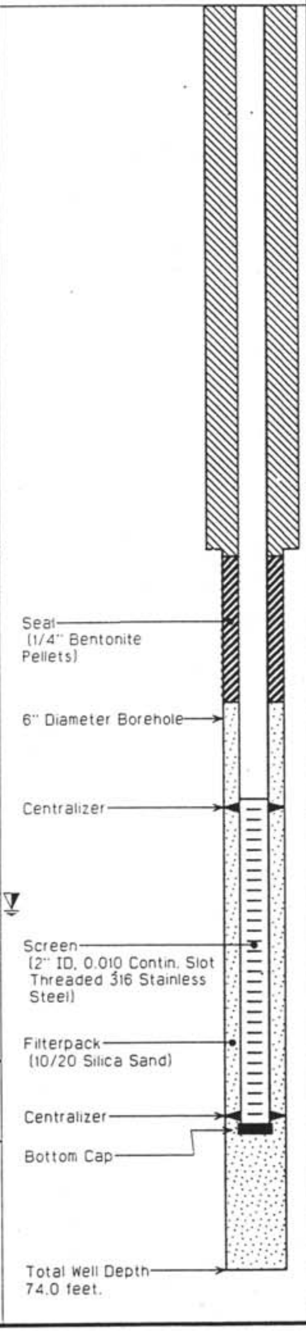
EAST (X): 755046.76

WELL STATUS/COMMENTS: ACTIVE

LOCATION: Upgradient of Disposal Cell

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	ELEVATION feet
				CL	slightly moist, very stiff (pp=3.5).	Qct	
	SS-15	24/24"	16		37.5 - 38.8' SILTY CLAY, weak red (2.5YR 6/4) some fine sand, soft (pp=1.75).		
40	SS-16	11/11"	87+	GC Chrt	38.8 - 41.5' CLAYEY GRAVEL, dry, relict angular chert fragments, matrix is predominantly silt and fine sand.	dPr	610
	SS-17	24/24"	70		41.5 - 46.5' CLAYEY GRAVEL, angular white chert fragments to 2", hard to very hard, interstitial clay is dark red (2.5YR 4/8), moist.		
45	SS-18	24/24"	51		46.5 - 51.8' CLAYEY GRAVEL, as above but strong brown (7.5YR 5/8), increased weathering of chert gravel (coarse sand size to 1").		605
	SS-19	22/24"	19				
50	SS-20	20/24"	22				600
	SS-21	4/4"	>50		Top of Bedrock @ 51.8 ft.		
	RUN-1	60/72"	52	lms chrt	51.8 - 65.6' ARGILLACOUS LIMESTONE (65%) AND CHERT (35%), brecciated and interbedded together. Limestone is grayish orange (10YR 7/4), very fine-grained, thin to very thin-bedded, moderately hard, moderately weathered with occasional vugs, slight to moderate porosity, slightly fossiliferous, closely fractured with FeOx staining. Chert is very light gray (N8), very hard, very fossiliferous. "Weathered Burlington-Keokuk Limestone".	Mbkw	
55							595
	RUN-2	53/60"	80		Increased vugginess below 58.5 feet.		
60							590
					Kp = CONSTANT HEAD SINGLE PACKER PRESSURE TESTS 55.2 to 63.5 ft. K < test method quantitation limit. 60.0 to 70.0 ft. K=4.9E-6 cm/sec		
	RUN-3	78/78"	59				
65							585
					65.6 - 70.0' ARGILLACEOUS LIMESTONE AND CHERT, as above but with less chert (25%), color is grayish orange (10YR 7/4) increased porosity and softer rock with silt on fractures. Chert is brecciated in "shattered"-looking schards. "Weathered Burlington- Keokuk Limestone"		
70					Total cored depth 70.0 feet. Switched to 6" air rotary and reamed hole to 74.0'.		580
					Note: Soil and rock color are indexed on the Muncell soil color chart. Split spoon sampler is 3" O.D., 2-1/2" I.D., therefore SPT results qualitative.		
75							575

WELL DIAGRAM



Sample Interval No Sample Taken ∇minimum ▼maximum ∇average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

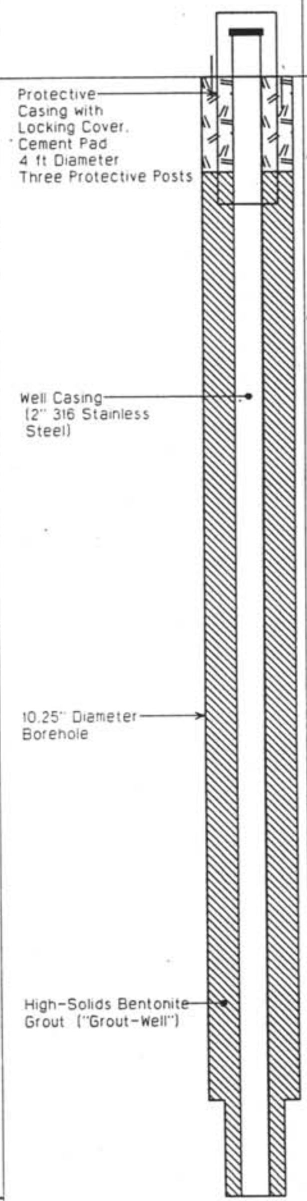
WSWLOG-C

HOLE NUMBER	MW-2047 (C4)
SHEET 1 OF 2	
NORTH (Y):	1044105.67
EAST (X):	754487.53
TOC ELEVATION	640.30
GROUND ELEVATION	637.48
STICKUP	2.82
HYDR CONDUCTIVITY (cm/sec)	K= 8.03x10^{-6} (Packer Test)

WELL STATUS/COMMENTS	ACTIVE
LOCATION	Upgradient of Disposal Cell
DRILLING CONTRACTOR	GEOTECHNOLOGY INC
DRILL RIG MAKE & MODEL	CME 750, HSA/NQWL CORE/SCHRAMM AIR ROT.
HOLE SIZE & METHOD	10 1/4" HSA to 32.0' then 6" Air
ANGLE FROM HORIZONTAL & BEARING	90
DEPTH (FT.) FROM GROUND ELEV. TO: BOTTOM OF HOLE (TD)	60.2
DRILL FLUIDS & ADDITIVES	WATER/AIR
CASING TYPE, DEPTH, SIZE	2" 316 STAINLESS STEEL
BEDROCK	44.5
DATE START	12-3-1996
DATE FINISH	12-10-1996
WATER LEVELS & DATES	
LITHOLOGY BY	PAUL PATCHIN

SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
			Fill	0 - 4.5' FILL, 3/4" crushed rock to 1 ft, 3" clean rock to 3.5', then silty clay fill with limestone gravel to 4.5'.	Fill
SS-1	17/24"	31	ML	SILT, light gray (2.5Y7/2), nonplastic, dry, hard (pp=4.5+) minor FeOx mottling.	Qpl
SS-2	14/24"	24	ML	CLAYEY SILT, mottled yellowish brown (10YR5/6) and light brownish gray (2.5Y 6/2), low plasticity, slightly moist, hard (pp=4.5+), minor FeOx and MnOx.	Qrx
SS-3	16/24"	18	CL	SILTY CLAY, mottled light brownish gray (2.5Y 6/2) and yellowish brown (10YR 5/6), low to medium plasticity, slightly moist, very stiff to hard (pp=4.5), minor silt as lenses in clay and minor fine chert gravel, FeOx nodules and MnOx streaking (fracture fill).	Qfv
SS-4	20/24"	22	CL	SANDY CLAY with GRAVEL, mottled yellowish brown (10YR 5/8) (primary) and minor light brownish gray (10YR 6/2), slightly moist, sandy with approx. 10% gravel (very fine to 2"), mostly angular chert with minor subrounded igneous, abundant FeOx and MnOx stain, very stiff to hard (pp= 3.75-4.5+) with near-vertical fractures exhibiting leaching (gray color) and MnOx staining.	Qct
SS-5	20/24"	16			
SS-6	21/24"	22	CL CH	SILTY CLAY, distinctive yellowish-red (5YR 4/6) moderate to high plasticity, slightly moist, no gravel or sand, soapy, very hard (pp=4.5+) stiff (pp=3.0).	pPr
SS-7	23/24"	65	GC	Harder drilling @ 19.0 ft. CLAYEY GRAVEL, approx. 75 - 80% angular chert gravel with plastic interstitial clay and minor sand pockets. Gravel is exclusively chert until approx. 26.0' then includes very weathered (to powder) limestone. Interstitial clay is dusky red (2.5YR 4/4), high plasticity, slightly moist, with pockets of distinctive yellow fine sand, abundant FeOx and minor MnOx stain on gravel, very dense.	
SS-8	7/7"	>50			
SS-9	11/11"	>50		Very hard drilling @ 27 ft.	
SS-10	22/24"	43		CLAYEY GRAVEL, as above, with weathered limestone pieces and powder. Sampler refusal @31.9 ft. Weathered limestone in sampler. Auger refusal @ 32.0 ft. Started NQ wireline coring.	
RUN-1	37/102"	8	chrt	32.0 - 35.6' CHERT, brecciated with minor argillaceous limestone and as nodules to .5' (minor) chert is light gray (N7) to minor mottled medium gray (N5), slightly weathered, very hard, very fossiliferous, closely fractured. Minor limestone is grayish- orange (10YR 7/4), argillaceous, moderately hard, brecciated, moderately	

WELL DIAGRAM



DEPTH feet: 5, 10, 15, 20, 25, 30, 35

ELEVATION feet: 635, 630, 625, 620, 615, 610, 605

Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

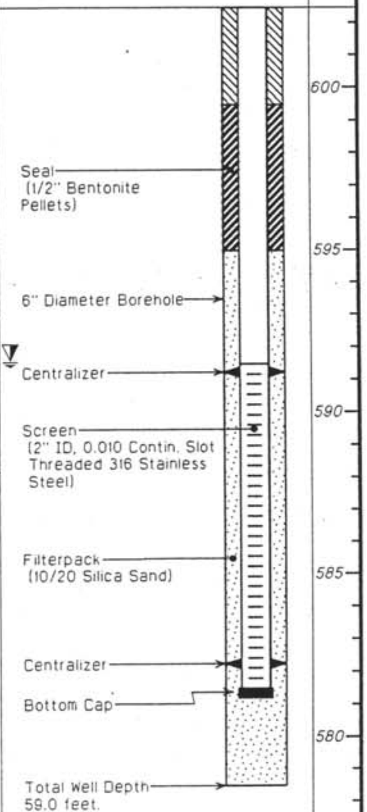
HOLE NUMBER	MW-2047 (C4)
SHEET 2 OF 2	
NORTH (Y):	1044105.67
EAST (X):	754487.53

WELL STATUS/COMMENTS ACTIVE

LOCATION Upgradient of Disposal Cell

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
						chrt	weathered, with FeOx stain, vuggy.	
						CL GC	35.6 - 44.4' GRAVELLY CLAY/CLAYEY GRAVEL, (Residuum), most of clay /gravel in interval not recovered in core barrel.	pPr
40		RUN-2	17/48"	0				
							44.4 - 44.5' CHERT, very light gray (N8), very hard, moderately weathered.	
45		RUN-3	72/72"	55		chrt	Top of Bedrock @ 44.5 ft.	
						lms chrt	44.5 - 49.8' ARGILLACEOUS LIMESTONE (60%) and CHERT (40%), brecciated and interbedded. Limestone is grayish orange (10YR 7/4) with minor dark yellowish orange (10YR 6/6), very argillaceous, very fine-grained, very thin-bedded (interbedding) and irregular brecciation with chert, moderate to high porosity, medium hardness, moderately to highly weathered, closely fractured, some secondary calcite. Chert is very light gray (N8) to pale orange (10YR 8/2), brecciated in thin irregular "beds" with limestone, slightly weathered, very hard, very fractured with MnOx infilling. "Strongly weathered Burlington-Keokuk Limestone"	Mbksw
50		RUN-4	116/116"	73		chrt	49.8 - 50.2' CHERT, mottled grayish orange (10YR 7/2) and very light gray (N8), very shattered and brecciated, very hard.	
55						lms chrt	50.2 - 60.2' ARGILLACEOUS DOLOMITIC LIMESTONE (70%) and CHERT (30%), in brecciated texture. Limestone is as above but is dolomitic with thicker bedding (thin-bedded), high porosity, and chert exhibiting a very anglular, brecciated and "shattered" texture. Color change (gradual) to more olive color and vuggy (bone-marrow) texture at about 58.5', Overall, moderately hard, moderate to highly weathered, with MnOx commonly lining fractures in chert. " Weathered Burlington- Keokuk Limestone"	Mbkw
60							Kp = CONSTANT HEAD SINGLE PACKER PRESSURE TEST 46.0 to 60.2 ft. K=8.0E-6 cm/sec	
							Total cored depth 60.2 feet. Switched to 6" air rotary and reamed hole to 59.0'.	
65							Note: Soil and rock color are indexed on the Muncell soil color chart. Split spoon sampler is 3" O.D., 2-1/2" I.D., therefore SPT results are qualitative.	
70								
75								

WELL DIAGRAM



Sample Interval No Sample Taken minimum maximum average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

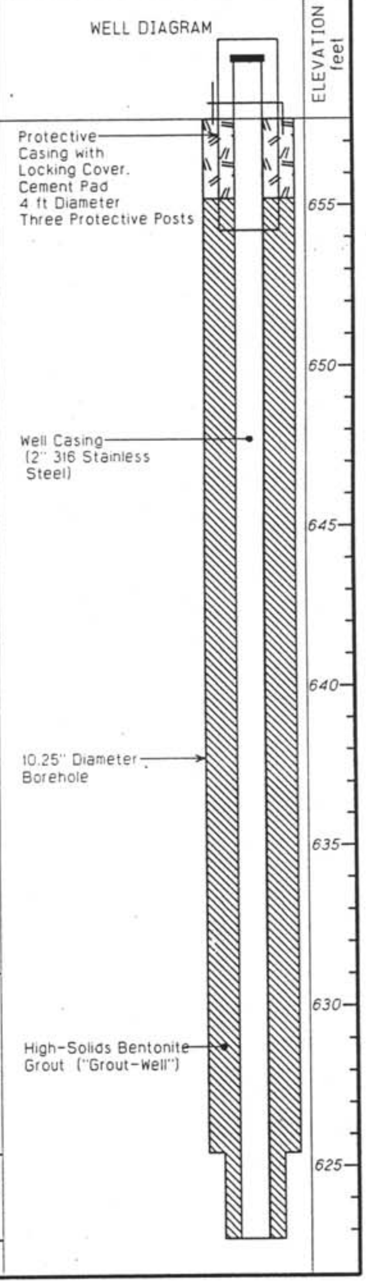
HOLE NUMBER	MW-2048 (C1)
SHEET	1 OF 2
NORTH (Y):	1042435.46
EAST (X):	755000.96
TOC ELEVATION	659.85
GROUND ELEVATION	657.72
STICKUP	2.13
HYDR CONDUCTIVITY (cm/sec)	K= 7.91×10^{-4} (Packer Test)

WELL STATUS/COMMENTS	ACTIVE
LOCATION	Upgradient of Disposal Cell
DRILLING CONTRACTOR	GEOTECHNOLOGY INC.
DRILL RIG MAKE & MODEL	CME 750, HSA/NQWL CORE/SCHRAMM AIR ROT.
HOLE SIZE & METHOD	10 1/4" HSA to 32.3' then 6" Air
ANGLE FROM HORIZONTAL & BEARING	90
DEPTH (FT.) FROM GROUND ELEV. TO: BOTTOM OF HOLE (TD)	60.0
BEDROCK	32.3
DRILL FLUIDS & ADDITIVES	WATER/AIR
CASING TYPE, DEPTH, SIZE	2" 316 STAINLESS STEEL
DATE START	12-12-1996
DATE FINISH	12-19-1996
WATER LEVELS & DATES	∇ ▼

LITHOLOGY BY PAUL PATCHIN

SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
			Fill	FILL, silty clay, dark brown, damp.	Fill
SS-1	15/24"	9	CL	SILTY CLAY, light brownish gray (2.5Y 6/2) with minor yellowish brown (10Y 5/6) mottling, medium plasticity, slightly moist, very stiff (pp=3.25), abundant FeOx nodules (2mm) and MnOx streaks.	Qfv
SS-2	14/24"	19	CH	CLAY, as above but with increased plasticity (high) and yellowish brown mottling, very stiff (pp=3.0), decrease in silt content and no gravel.	Qfv
SS-3	21/24"	16		CLAY, as above, very stiff (pp+3.0).	Qfv
SS-4	23/24"	13		CLAY, as above, very stiff (pp=2.75), minor coarse sand-size chert at bottom.	Qfv
SS-5	22/24"	12	CL CH	SILTY CLAY, as above, increase in yellowish brown color, MnOx streaking, and coarse sand and fine gravel content at bottom of sample, very stiff (pp=3.0).	Qfv
SS-6	23/24"	19	CL	SANDY CLAY with GRAVEL, yellowish brown (10YR 5/8) with minor light brownish gray (2.5Y 6/2) mottling, medium plasticity, slightly moist, hard (pp=4.5+), contains approx. 10% angular weathered chert gravel (coarse sand size to 1"), abundant MnOx streaks and FeOx stain.	Qct
SS-7	24/24"	16		SANDY CLAY with GRAVEL, as above, increased moisture (moist), very stiff (pp=2.75), with minor softer zones.	Qct
SS-8	24/24"	15	CL CH	CLAY, mottled strong brown (7.5YR 5/6) and dark red (2.5YR 4/6), medium to high plasticity, moist, no sand, trace v. fine gravel, abundant MnOx, streaks.	Qct
SS-9	24/24"	18	CL CH	CLAY with GRAVEL, strong brown (7.5YR 5/6) with minor light gray, medium to high plasticity, slightly moist, very stiff (pp=3.5+), contains no sand and approx. 10-15% very fine to 1.5" gravel (chert and igneous), abundant MnOx streaks (increasing with depth), last .5' very gravelly with very abundant MnOx and FeOx nodules.	Qct
SS-10	19/24"	30	CL	GRAVELLY CLAY, strong brown (7.5 YR 5/6), high plasticity, approx. 40% angular chert gravel and minor limestone gravel, clay is moist with FeOx nodules and MnOx streaks and conspicuous calcareous sand pocket (decomposed rock?) at 26.5-27.0'.	pPr
SS-11	9/14"	+91			pPr
SS-12	11/18"	24	CL GC	GRAVELLY CLAY, as above but siltier and sandier, contains decomposed limestone, chert, hard, damp.	pPr
RUN-1	36/78"	9	lms chrt	GRAVELLY CLAY/CLAYEY GRAVEL, as above but increased gravel (approx. 50%), hard, damp. Top of Bedrock @ 32.3 ft.	Mbksw
				32.3 - 41.6' ARGILLACOUS LIMESTONE AND CHERT, interbedded and breccieated. Approximately 70% limestone which is grayish orange (10YR 7/4) fine-grained, thin-bedded, slightly to highly	Mbksw

DEPTH feet: 5, 10, 15, 20, 25, 30, 35



▮ Sample Interval ☐ No Sample Taken ∇ minimum ▼ maximum ⊽ average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER	MW-2048 (C1)
SHEET 2 OF 2	
NORTH (Y):	1042435.46
EAST (X):	755000.96

WELL STATUS/COMMENTS: ACTIVE

LOCATION: Upgradient of Disposal Cell

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class
35–41.8				lms chrt
~39.5	RUN-2	18/34"	0	
~42	RUN-3	60/64"	49	
41.8–43.0				GC chrt
43.0–44.5				CL chrt
44.5–59.3				lms chrt
~48	RUN-4	12/24"	20	
~49.5	RUN-5	54/60"	54	
~54.5	RUN-6	60/60"	66	

DESCRIPTION AND REMARKS

weathered, moderately hard to hard, with weathered pyrite crystals in matrix and locally heavy FeOx staining and vugginess. Closely to very closely fractured with minor clay, stylolites, and fossils. Chert is brecciated and interbedded with limestone and in beds up to .8'. Color varies from white (N9) to grayish orange (10YR 7/4) to light bluish gray (5B 7/1), generally very hard, cryptocrystalline, fossiliferous with sealed fractures and MnOx infilling. Entire interval has numerous small void zones (bit drops) with a void from 40.5-41.2' showing very weathered residual chert gravel and clay. Overall, slight to moderate porosity. "Strongly Weathered Burlington-Keokuk Limestone"

41.8 - 43.0' CHERT GRAVEL, (void fill) with minor clay. Chert is very weathered and vuggy. providing a breccia appearance. Chert, white to bluish to pinkish.

43.0 - 44.5 SILTY CLAY with GRAVEL, brown (10YR 5/3), void fill.

44.5 - 59.3 ARGILLACEOUS LIMESTONE and CHERT, as above. Limestone exhibits stronger iron oxide staining (color to dark yellowish orange 10YR 6/6), moderate to high porosity, abundant solution features (vugs) pinpoint to 1/2", numerous small voids (bit drops) to approx. 51.5. Less vugs below 53.5. Minor intervals of medium crystalline limestone. Some secondary calcite in matrix. Chert is brecciated, bedded (to .5'), and nodular. "Strongly Weathered Burlington-Keokuk Limestone"

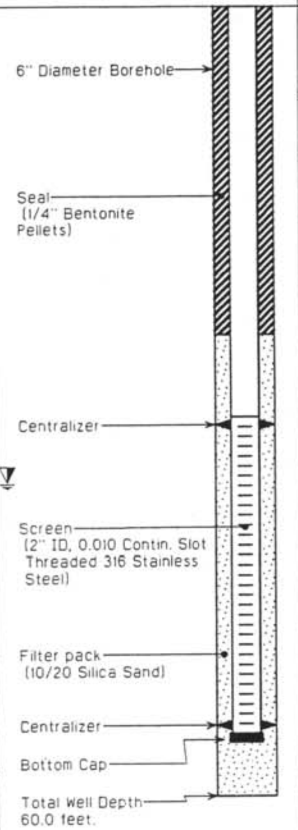
Kp = CONSTANT HEAD SINGLE PACKER PRESSURE TESTS
35.5 to 47.3 ft. K=7.9E-4 cm/sec
46.4 to 59.3 ft. K=6.8E-4 cm/sec

Total cored depth 59.3 feet. Switched to 6" air rotary and reamed hole to 60.0.

Note: Split spoon sampler is 3" O.D., 2-1/2" I.D., therefore SPT results are qualitative. Soil and rock colors are indexed on the Muncell soil color chart.

STRAT. UNIT: Mbksw

WELL DIAGRAM



ELEVATION feet: 620, 615, 610, 605, 600, 595, 590, 585

DEPTH feet: 40, 45, 50, 55, 60, 65, 70, 75

Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

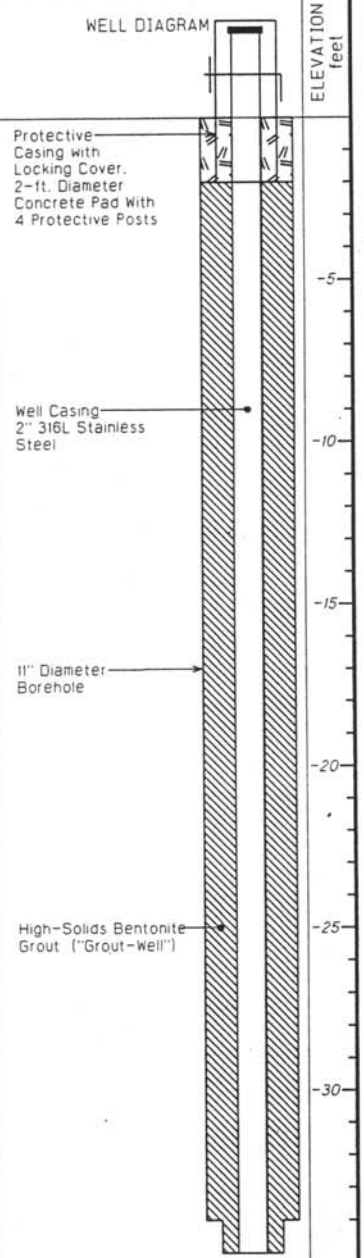
WSWLOG-C

HOLE NUMBER	MW-2048 (a)
SHEET 1 OF 2	
NORTH (Y):	
EAST (X):	
TOC ELEVATION	
GROUND ELEVATION	
STICKUP	
HYDR CONDUCTIVITY (cm/sec)	$K= 7.91x10^{-4}$ (Packer Test)

WELL STATUS/COMMENTS	ACTIVE
DRILLING CONTRACTOR	LAYNE WESTERN Inc.
HOLE SIZE & METHOD	9" HSA-34; NQ-62; 6" AIR-63
DRILL FLUIDS & ADDITIVES	Water core; Air ream
DATE START	11-9-01
LOCATION	SO. OF DISPOSAL CELL; PERIMETER WELL
DRILL RIG MAKE & MODEL	CME-750 HSA/NQWL; I-R TH-60 AIR ROTARY
ANGLE FROM HORIZONTAL & BEARING	Vertical
CASING TYPE, DEPTH, SIZE	2" 316 SS Mon. Well
DATE FINISH	12-5-01, Mon. Well
DEPTH (FT.) FROM GROUND ELEV. TO: BOTTOM OF HOLE (TD)	63.0, 62.0 Mon. Well
BEDROCK	32.5
WATER LEVELS & DATES	

LITHOLOGY BY ALAN BENFER

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery (0–100)	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
0–28.0							Soil not sampled or logged from the surface to 28.0-ft.	Qct/Qrc undiff.
28		SPT-1		9		CH	CLAY, high plasticity, ~40% angular chert and weathered limestone gravel, mostly yellow brown, moist, firm CH. Residuum.	pPr
30		SPT-2		14			CLAY, gravelly to clayey gravel, high plasticity clay, reddish brown, moist, hard, CH-GC. Residuum.	pPr
32		SPT-3		76+		CHRT LMS	LIMESTONE, weathered, white to yellowish brown, dry, hard.	Mbk
34							Auger refusal at 34.0-ft. Continue with NQ core.	Mbk
34.5		NQ-1	31/66"	15			NQ-1, 34.0'- 39.5'. Poor recovery, loss zones unknown. Lost circulation at 34.5' permaently.	Mbk



Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

HOLE NUMBER: MW-2048 (a)

SHEET 2 OF 2

NORTH (Y):

EAST (X):

WELL STATUS/COMMENTS: ACTIVE

LOCATION: SO. OF DISPOSAL CELL; PERIMETER WELL

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery (0–100)	N# or RQD	SOIL/ROCK class	STRAT. UNIT
35–40				CHRT / LMS	Mbk
40	NQ-2	28/40"	62		Mbk
43	NQ-3	52/70"	13		Mbkw
49	NQ-4	58/67"	54		Mbksw
54	NQ-5	91/94"	77		Mbksw

DESCRIPTION AND REMARKS

LIMESTONE, slightly weathered, crystalline-grained, locally argillaceous, with specks and thin streaks of MnOx, fossiliferous, light gray to light yellowish brown, vugs up to 1" near bottom of core, some interbedded light gray chert. Rock is relatively fresh, hard, with minimal oxidation. Two clay seams near core bottom; one is 3-1/2" thick with angular chert fragments, lower one is 6" of massive clay with some fine gravel, high plasticity, yellow brown, minor MnOx. Burlington-Keokuk Limestone.

@ 39.5'- 42.8'. LIMESTONE as above, becoming oxidized at ~39.7', some styolites, ~30% scattered chert, appears brecciated, fossiliferous, mostly light gray. Up to 4+ fractures per foot, rough, open, oxidized.

@ 41.5'. Scattered oxidized sulfides, increased limestone weathering at 42.7'. Bit dropped at ~41.8' to ~42.5'. Weathered Burlington- Keokuk Limestone.

@ 43.5'- 44.1'. CHERT, hard, white, light and blue gray.

@44.6'- 45.0'. Silty clay with limestone fragments.

@ 45.4'- 48.6'. LIMESTONE, moderately weathered, moderate solutioning with vugs up to 1", generally coarse-grained, some argillaceous, FeOx staining with thin streaks of MnOx, mostly light yellow brown, with ~ 30% scattered interbedded chert, generally light gray.

@ 48.2'- 52.0'. CHERT, hard, with thin streaks of MnOx, fracture surfaces oxidized, white to pale yellow, with up to ~25% thinly interbedded limestone, strongly weathered at 49.2-ft., soft, argillaceous, dark yellowish orange. At 50.1 to 52.0-ft., limestone is very vuggy along bedding; clayey. One to 4+ fractures per foot, rough; broken. Strongly weathered Burlington-Keokuk Limestone.

@ 52.0'- 53.8'. CHERT, hard, bluish gray with ~40% limestone, strongly weathered, argillaceous, generally interbedded, a few vugs, yellowish orange.

@ ~53.7'. Cut fast. Very vuggy at 53.8-ft.

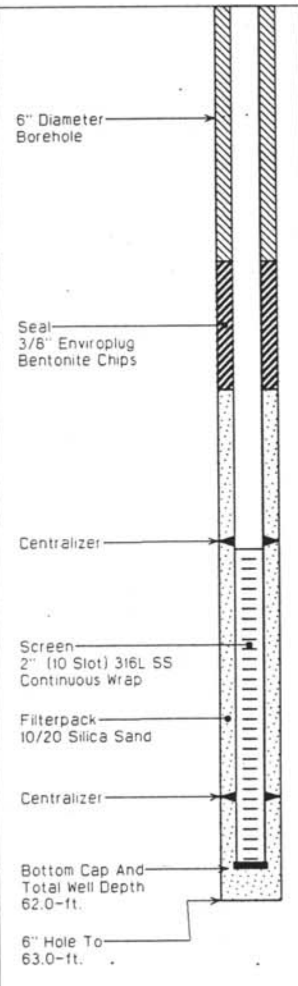
CHERT AND LIMESTONE as above, ~40% limestone, strongly weathered, locally can be scratched with fingernail, a few vugs. Chert is bluish gray, locally fossiliferous. One to 3+ fractures per foot, rough, open, some broken.

@ 60.5'. 1/2" patch of oxidized pyrite.

Total cored depth 62.0', 11-15-01. Hole reamed to 6" diameter to 63.0' and a 2" monitoring well was constructed.

Packer testing was not performed.

WELL DIAGRAM



ELEVATION feet: -40, -45, -50, -55, -60, -65, -70

Sample Interval | No Sample Taken | minimum | maximum | average

WSWLOG-C

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

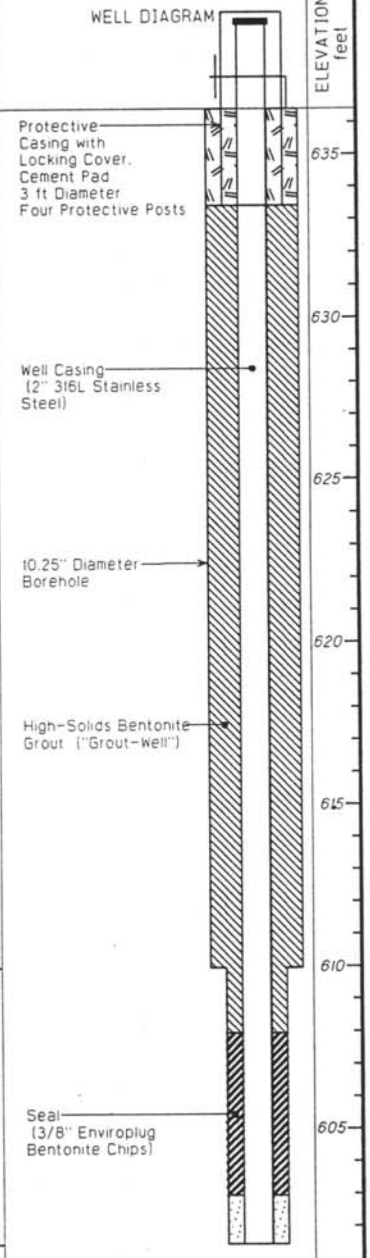
HOLE NUMBER MW-2051	**SHEET** 1 OF 2	**NORTH (Y):** 1042175.97	**EAST (X):** 753129.19
WELL STATUS/COMMENTS ACTIVE	**LOCATION** NORTHEAST EDGE OF DISPOSAL CELL	**TOC ELEVATION** 639.77	
DRILLING CONTRACTOR LAYNE WESTERN Inc.	**DRILL RIG MAKE & MODEL** CME-750ATV HSA/NQWL CORE/SCHRAMM AIR ROT	**GROUND ELEVATION** 636.43	
HOLE SIZE & METHOD 7 1/4" Auger to 26.5' then 6" Air	**ANGLE FROM HORIZONTAL & BEARING** Vertical	**BOTTOM OF HOLE (TD)** 49.0	**STICKUP** 3.34
DRILL FLUIDS & ADDITIVES WATER/AIR	**CASING TYPE, DEPTH, SIZE** 2" 316L Stainless Steel	**BEDROCK** 26.5	**HYDR CONDUCTIVITY (cm/sec)** K= 8.7×10^{-3} (Packer Test)
DATE START 5-2-2000	**DATE FINISH** 5-30-2000	**WATER LEVELS & DATES**	

DEPTH (FT.) FROM GROUND ELEV. TO:

LITHOLOGY BY ALAN BENFER/PAUL PATCHIN

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
0				fill	FILL, (silty clay)	Fill
				CH	CLAY, high plasticity, mottled yellow brown and light gray, approx. 10% fine white sand, moderate black MnOx, firm, moist, CH.	Qct
	SPT-2		5	CH	CLAY, high plasticity with some sand and gravel (angular), MnOx, mottled yellow brown and light gray and black, moist, hard, CH.	Qct
	SPT-3		12		Lenses of clean fine sand between 5 and 6 ft.	Qct
5	SPT-4		18		CLAY, as above, approx. 10% fine sand and some fine gravel, hard, MnOx on vertical fracture surfaces, CH.	Qct
	SPT-5		12			Qct
10	SPT-6		14			Qct
	SPT-7		23	CL	SILTY CLAY, low plasticity, with weathered FeOx nodules, light gray, moist, hard, CL.	Qct
	SPT-8		14	CH	CLAY, high plasticity, FeOx nodules, trace fine gravel, mottled light brown and light gray, moist, hard, CH.	Qct
15	SPT-9		10	CH	CLAY, as above but more reddish brown, high plasticity, with some angular chert gravel, CH.	dPr
	SPT-10		8			dPr
20	SPT-11		7			dPr
	SPT-12		15			dPr
	SPT-13		19			dPr
25					Sampler refusal at 25.9 ft. Augered to top of rock at 26.5 ft (auger refusal).	dPr
	RUN-1	38/60"	8	chrt lms	26.5' - 35.3' CHERT AND ARGILLACEOUS LIMESTONE (approx 65%/35%). Chert is very light gray (N8) to minor medium light gray (N6), brecciated to very thinnly bedded with limestone, very hard, slightly to moderately weathered, fossiliferous, with MnOx and FeOx staining (MnOx on microfractures in chert). Limestone is grayish orange (10YR7/4), mod. weathered, mod. hard, with vugs pinpoint to 3 mm, fine grained, very thinly bedded (interbedded with chert), slightly fossiliferous with FeOx staining (particularly in possible void zones at 28.0' - 28.5' and 34.0'-34.7').	Mbkw
30	RUN-2	47/60"	46		Lost circulation at 29.0'	Mbkw
35					Possible voids from 34.0 - 34.7'	Mbkw

WELL DIAGRAM



Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSMLOG-C

HOLE NUMBER	MW-2051
SHEET 2 OF 2	
NORTH (Y):	1042175.97
EAST (X):	753129.19

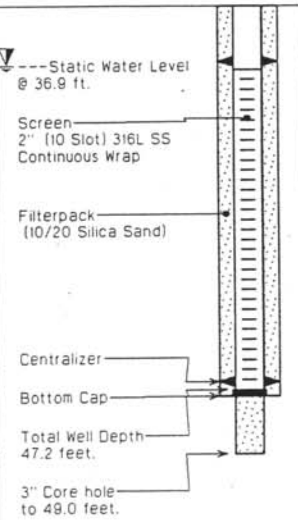
WELL STATUS/COMMENTS: ACTIVE

LOCATION: NORTHEAST EDGE OF DISPOSAL CELL

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT
35.3–43.7		RUN-3	43/60"	48		chrt / lms / lms chrt	35.3' - 43.7' ARGILLACEOUS LIMESTONE (70%) and CHERT (30%) as above but increased limestone. Inreased vugs (to 1") parallel with bedding, moderately weathered. Probable voids @34.0' - 34.7' and 36.5' - 38.0' with heavy FeOx staining and residual chert gravel. Semi-fresh pyrite specks @33.5'. MnOx specks @39.5' with increased FeOx and weathering. Yellowish coloring (clay) at 40.3' - 41.5' with hematite blebs.	Mbkw
		RUN-4	46/90"	37			41.5 - 43.2' Core loss possibly caused by caved material grinding core.	Mbkw
43.7–49.0						lms chrt	43.7' - 49.0' ARGILLACEOUS LIMESTONE, as above but color to more gray and porosity increase with CHERT (<30%) brecciated but also as large 4" irregular nodules, very fossiliferous, occasional calcite-rich (as medium grained crystals), bands to 1.5", occasional vugs, slightly weathered, abundant MnOx specks.	Mbkw
							Total cored depth 49.0'. Reamed hole to 6" to 47.2' and installed 2" monitoring well.	
							Note: Color is from the GSA rock color chart.	
							CONSTANT HEAD SINGLE PACKER TEST RESULTS: 30.5 - 41.5 ft. K=8.7E-3 cm/sec; 36.1 - 49.0 ft. K=7.2E-3 cm/sec	

DEPTH scale (feet): 40, 45, 50, 55, 60, 65, 70, 75

WELL DIAGRAM



ELEVATION feet: 600, 595, 590, 585, 580, 575, 570, 565

Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▽average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

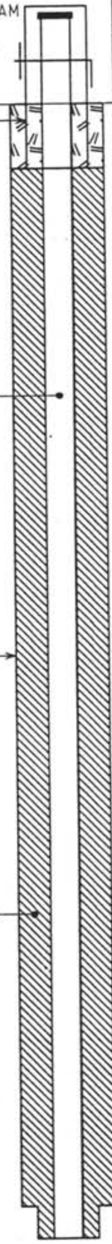
HOLE NUMBER	MW-2055
SHEET 1 OF 2	
NORTH (Y):	1042419.92
EAST (X):	755000.58
TOC ELEVATION	662.62
GROUND ELEVATION	659.86
STICKUP	2.76
HYDR CONDUCTIVITY (cm/sec)	K= $1.5x10^{-5}$ (Packer Test)

WELL STATUS/COMMENTS	ACTIVE
LOCATION	SO. OF DISPOSAL CELL; PERIMETER WELL
DRILLING CONTRACTOR	LAYNE WESTERN Inc.
DRILL RIG MAKE & MODEL	CME-750 HSA/NQWL; I-R TH-60 AIR ROTARY
HOLE SIZE & METHOD	9" HSA-34; NQ-62; 6" AIR-63
ANGLE FROM HORIZONTAL & BEARING	Vertical
DRILL FLUIDS & ADDITIVES	Water core; Air ream
CASING TYPE, DEPTH, SIZE	2" 316 SS Mon. Well
DATE START	11-9-01
DATE FINISH	12-5-01, Mon. Well
DEPTH (FT.) FROM GROUND ELEV. TO: BOTTOM OF HOLE (TD)	63.0
BEDROCK	32.5
WATER LEVELS & DATES	

LITHOLOGY BY ALAN BENFER

DEPTH feet	SAMPLE	SAMPLE/RUN Number	PERCENT Recovery (0–100)	N# or RQD	GRAPHIC LOG	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	ELEVATION feet
0–28.0							Soil not sampled or logged from the surface to 28.0-ft.	Qct/Qfc undiff.	
5									655
10									650
15									645
20									640
25									635
28		SPT-1		9		CH	CLAY, high plasticity, ~40% angular chert and weathered limestone gravel, mostly yellow brown, moist, firm CH. Residuum.	pPr	
30		SPT-2		14			CLAY, gravelly to clayey gravel, high plasticity clay, reddish brown, moist, hard, CH-GC. Residuum.		630
32		SPT-3		76+		CHRT LMS	LIMESTONE, weathered, white to yellowish brown, dry, hard.	Mbk	
34		NQ-1	31/66"	15			Auger refusal at 34.0-ft. Continue with NQ core.		625
35							NQ-1, 34.0'- 39.5'. Poor recovery, loss zones unknown. Lost circulation at 34.5' permaently.		

WELL DIAGRAM



Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▽average

WELDON SPRING SITE REMEDIAL ACTION PROJECT

BOREHOLE AND WELL COMPLETION LOG

WSWLOG-C

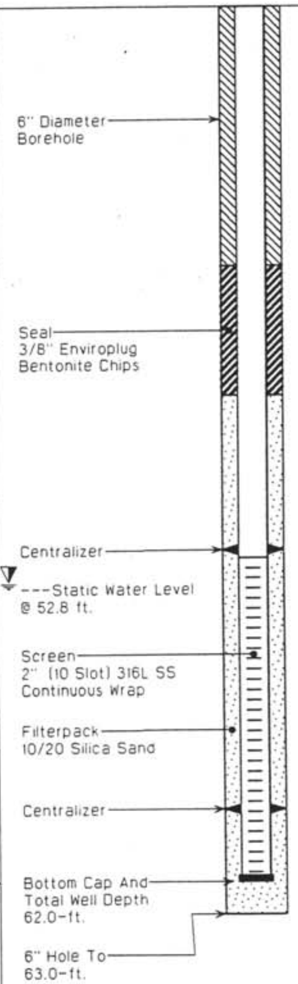
HOLE NUMBER	MW-2055
SHEET 2 OF 2	
NORTH (Y):	1042419.92
EAST (X):	755000.58

WELL STATUS/COMMENTS: ACTIVE

LOCATION: SO. OF DISPOSAL CELL; PERIMETER WELL

DEPTH feet	SAMPLE/RUN Number	PERCENT Recovery	N# or RQD	SOIL/ROCK class	DESCRIPTION AND REMARKS	STRAT. UNIT	ELEVATION feet
				CHRT LMS	LIMESTONE, slightly weathered, crystalline-grained, locally argillaceous, with specks and thin streaks of MnOx, fossiliferous, light gray to light yellowish brown, vugs up to 1" near bottom of core, some interbedded light gray chert. Rock is relatively fresh, hard, with minimal oxidation. Two clay seams near core bottom; one is 3-1/2" thick with angular chert fragments, lower one is 6" of massive clay with some fine gravel, high plasticity, yellow brown, minor MnOx. Burlington-Keokuk Limestone.	Mdk	
40	NQ-2	28/40"	62		@ 39.5'- 42.8'. LIMESTONE as above, becoming oxidized at ~39.7', some styolites, ~30% scattered chert, appears brecciated, fossiliferous, mostly light gray. Up to 4+ fractures per foot, rough, open, oxidized.		620
	NQ-3	52/70"	13		@ 41.5'. Scattered oxidized sulfides, increased limestone weathering at 42.7'. Bit dropped at ~41.8' to ~42.5'. Weathered Burlington- Keokuk Limestone.	Mbkw	
45					@ 43.5'- 44.1'. CHERT, hard, white, light and blue gray.		615
					@44.6'- 45.0'. Silty clay with limestone fragments.		
	NQ-4	58/67"	54		@ 45.4'- 48.6'. LIMESTONE, moderately weathered, moderate solutioning with vugs up to 1", generally coarse-grained, some argillaceous, FeOx staining with thin streaks of MnOx, mostly light yellow brown, with ~ 30% scattered interbedded chert, generally light gray.		
50					@ 48.2'- 52.0'. CHERT, hard, with thin streaks of MnOx, fracture surfaces oxidized, white to pale yellow, with up to ~25% thinly interbedded limestone, strongly weathered at 49.2-ft., soft, argillaceous, dark yellowish orange. At 50.1 to 52.0-ft., limestone is very vuggy along bedding; clayey. One to 4+ fractures per foot, rough; broken. Strongly Weathered Burlington-Keokuk Limestone.	Mbksw	610
55	NQ-5	91/94"	77		@ 52.0'- 53.8'. CHERT, hard, bluish gray with ~40% limestone, strongly weathered, argillaceous, generally interbedded, a few vugs, yellowish orange.		605
					@ ~53.7'. Cut fast. Very vuggy at 53.8-ft.		
60					CHERT AND LIMESTONE as above, ~40% limestone, strongly weathered, locally can be scratched with fingernail, a few vugs. Chert is bluish gray, locally fossiliferous. One to 3+ fractures per foot, rough, open, some broken.		600
					@ 60.5'. 1/2" patch of oxidized pyrite.		
					Total cored depth 62.0', 11-15-01. Hole reamed to 6" diameter to 63.0' and a 2" monitoring well was constructed.		
65							595
					Packer testing was not performed.		
70							590
75							585

WELL DIAGRAM



Sample Interval ☐ No Sample Taken ▽minimum ▼maximum ▼average

APPENDIX B

Statistical Evaluation of Detection Monitoring Data (1998 to 2001)

Statistical Evaluation of Detection Monitoring Data

B.1 Evaluation Summary – 1998 through 2001

Under the original version of this plan, the elements of the detection monitoring program included:

- Collecting four replicate samples at each location on a semiannual basis,
- Measuring groundwater elevation at each well location, as well as flow rate for the spring, on a quarterly schedule and immediately prior to each semiannual sampling event,
- Analyzing for the entire list of constituents presented in Table 3-2 of the main text of this report, and noting any unusual colors, odors, or turbidity,
- Evaluating analytical data in comparison with background levels to identify statistically significant increases that may indicate an impact from the disposal cell, and
- For parameters that appear to exceed background levels: reviewing analytical results for potential errors, evaluating cell leachate volume data to confirm liner integrity, and resampling individual locations for the suspect parameters.

The detection monitoring data obtained from 1998 to 2001 were evaluated in accordance with the U. S. EPA guidance on *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (Ref. B-1). This document provides guidance on conducting various types of statistical analyses under the RCRA groundwater monitoring regulations (40 CFR 264, Subpart F). The foundational assumption of each statistical method is that the waste management unit is situated on a uncontaminated aquifer and that the only source of increases in contaminant concentrations in the groundwater is leakage from the waste management unit. The guidance cautions against the use of the prescribed methods in evaluating data from wells that have shown evidence of preexisting contamination or where a high degree of spatial variation exists between the background wells and compliance wells, both of which are true for the Weldon Spring site.

In the absence of regulatory guidance on more appropriate statistical methods for use at a site with preexisting groundwater contamination, detection monitoring data have been evaluated by several different methods, as discussed below.

B.1.1 1998 Results

Detection monitoring data from 1998 were evaluated by means of both parametric and nonparametric analysis of variances (ANOVA) analyses. Results of these analyses, which are presented in the *Weldon Spring Site Environmental Report for Calendar Year 1998* (Ref. B-2), are based on a comparison of data from the compliance wells, MW-2032 and MW-2045 through MW-2047, with data from the upgradient (i.e., "background") well, MW-2048. These analyses resulted in a large number of statistical failures which, if they had been based on data from a previously uncontaminated aquifer, would have provided evidence of groundwater impact due to the disposal cell.

Many of the test failures were determined to be attributable to preexisting concentrations of certain parameters being higher in the compliance wells than in the upgradient well prior to waste placement (March 1998). However, after disregarding the parameters in which this was the case, the following parameters still failed at least one of the statistical tests:

- MW-2032 Chromium, silver, thallium
- MW-2045 Calcium, radium-228
- MW-2046 Silver, vanadium, TOX
- MW-2047 Vanadium, zinc, 1,3,5-TNB

The monitoring data for parameters that failed the interwell comparisons were further evaluated by means of ANOVA procedures based on intrawell comparisons with baseline data from the same locations. This testing resulted in the following statistical failures:

- MW-2045 Calcium
- MW-2046 Vanadium
- MW-2047 Vanadium, 1,3,5-TNB

All of the above statistical failures were attributed to natural fluctuations in the existing groundwater quality. It was not reasonable to consider these test failures to be indicators of cell leakage because waste placement, and subsequent leachate production, began only a few months before the first 1998 detection monitoring event, and contaminant fate and transport analyses had predicted a 53-year interval before contaminants leaking from the cell would be detected in the monitoring wells (Ref. B-3). In addition, the use of the upgradient well, MW-2048, as a "background" well was determined to be inappropriate since several constituents were already higher in this well than in any of the compliance wells before waste placement began.

B.1.2 1999 Results

The detection monitoring program was modified in 1999, after review of the previous two years of groundwater and leachate data. Several parameters were eliminated from the monitoring list. Also, the monitoring frequency was reduced to a single sample obtained semiannually from each location instead of the four replicates previously collected.

In an effort to derive a more reliable means of evaluating data, an intrawell tolerance interval approach was used to evaluate the 1999 data instead of the ANOVA procedures used the previous year. A intrawell tolerance limit approach was considered the preferred method of evaluating data because this approach resulted in fewer false positive results that any of the other types of statistical analyses performed to date. Also, due to the heterogeneous nature of the aquifer it can be expected that each well would act independently because it monitors a discrete portion of the aquifer. By this method, each monitoring location (including the upgradient well) was considered to be a point of compliance, and "background" conditions were described by the contaminant concentrations measured at each location during baseline monitoring. Tolerance limits were calculated for each parameter at each monitoring location according to the methodology in *Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities* (Ref. 10).

Using the baseline data collected prior to waste placement, upper tolerance limits were established based on the assumptions of a normal data distribution and a 95% level of confidence. Data from the two semiannual monitoring events were compared to the baseline values, and any exceedances were investigated through the data verification process, sample reanalysis, and/or resampling. All confirmed exceedances were reported as statistically significant increases. The *Weldon Spring Site Environmental Report for Calendar Year 1999* (Ref. B-4) summarizes the results of statistical analysis of the 1999 data, in which the following parameters exceeded baseline for at least one of the sampling events:

- MW-2032 Chemical oxygen demand (COD), chromium, nickel
- MW-2045 Arsenic, chromium, molybdenum, nickel
- MW-2046 Aluminum, barium, chromium, magnesium, nickel, COD
- MW-2047 COD
- MW-2048 Magnesium, sulfate

As in the previous two years, the above statistical failures were attributed to natural fluctuations in the existing groundwater quality. However, in accordance with the original version of this plan, a thorough study of the monitoring network was conducted in 2000 to confirm that the recurring baseline exceedances were not true indicators of cell leakage. This study was documented in the *Weldon Spring Site Cell Groundwater Monitoring Demonstration Report* (Ref. B-5). It included an evaluation of historical site-wide groundwater quality, review of leachate flow rate and analytical data, analysis of groundwater elevation fluctuations, comparison of filtered and unfiltered samples for metals analysis, and review of cell well construction and performance information.

The demonstration report concluded that the baseline exceedances were not due to contaminant migration from the cell, but rather were the result of variations in previously existing groundwater contamination compounded by poor hydraulic performance of some of the wells. The following actions were recommended to alleviate the recurrence of similarly false positive results in future sampling events:

- Attempt to improve the flow rate and clarity of groundwater in MW-2045 by redeveloping it prior to the next sampling event,
- Install an additional compliance well in the vicinity of MW-2045 to provide supplemental monitoring on the northeast side of the disposal cell, and
- Recalculate the upper tolerance limit for the baseline values of each parameter at each well. The new limits should be based on the assumption that the four replicates obtained during each quarterly baseline event were not truly independent samples but represented a single event.

Results of the filtered metals analyses confirmed that most of the metals exceedances coincided with high turbidity and likely resulted from metals adhering to suspended clay particles in the groundwater. Although the filtering of groundwater samples for metals analyses is an acceptable sampling procedure, it was not listed as a recommendation in the demonstration report because baseline values were already established using unfiltered samples.

B.1.3 2000 Results

The recommendations from the demonstration report were implemented, and the 2000 data were evaluated using the tolerance interval approach with the recalculated tolerance limits. The *Weldon Spring Site Environmental Report for Calendar Year 2000* (Ref. 13) contains the results of this evaluation, in which the following parameters exceeded the new baseline tolerance limits during at least one of the semiannual sampling events:

- MW-2045 Chromium, molybdenum
- MW-2046 Molybdenum
- MW-2047 Chromium
- MW-2048 Chromium, magnesium, molybdenum, sulfate

B.1.4 2001 Results

Results of the 2001 detection sampling, which were evaluated in the same manner as in the previous year, are presented in the *Weldon Spring Site Environmental Report for Calendar Year 2001* (Ref. 14). The following parameters were identified as exceeding baseline tolerance limits during at least one of the semiannual sampling events:

- MW-2045 Chromium, molybdenum, nickel
- MW-2046 Nickel, 2,4,6-TNT
- MW-2048 Sulfate

Two new wells were installed and one was abandoned under the disposal cell monitoring program in 2001. MW-2051 and MW-2055 were installed and MW-2048 was abandoned.

Baseline monitoring data was collected from these wells in 2001 and 2002, and they were added to the detection monitoring program in 2002.

B.2 Evaluation Summary –2004

In response to a comment from the MDNR regarding the distribution of the groundwater data from the disposal cell wells, a statistical evaluation of the data was performed. This analysis consisted of a determination of the data distribution and the appropriateness of the baseline tolerance limits for evaluation of the detection monitoring data.

B.2.1 Data Distribution

The data for the signature parameters at locations MW-2032, MW-2046, MW-2047, MW-2051, MW-2055, and SP-6301 were reexamined to determine whether the data is Normal or log-Normal. Testing for Normality or log-Normality were done by three (3) different methods, as suggested as alternative tests in the *EPA Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities – Addendum to Interim Final Guidance* (Ref. B-6). These tests were:

1. Probability Plot Correlation Coefficient
2. Shaprio-Wilk Test of Normality (n<50) or Shaprio-Francia Test of Normality (n>50)
3. Coefficient of Skewness

The tests were performed for both the non-transformed data and log-transformed data for each of the four signature parameters at each location. Each of the signature parameters at each of the locations passed at least one of the three tests for Normality and log-Normality. For example, at location MW-2051 the results were:

Analyte	Test Method					
	PPCC	CS	SW/SF	PPCC	CS	SW/SF
	Non-transformed Data			Log-transformed Data		
Barium	N		N	N	N	N
Iron		N			N	
Manganese	N	N	N	N	N	N
Uranium	N		N	N	N	N

PPCC – Probability Plot Correlation Coefficient
CS – Coefficient of Skewness
SW – Shapiro-Wilk Test of Normality (n<50)
SF – Shapiro-Francia Test of Normality (n>50)
N – Criteria for Normality met

The other locations show similar results. Although the data shows a slightly stronger evidence of log-Normality than Normality, the data can be treated as Normal because of the difficulty in calculating the mean and variance/standard deviation for a log-Normal distribution.

B.2.2 Review of Baseline Tolerance Limits

All the available data was used in calculating baseline tolerance limits. Data points that may have been compromised in some manner should be excluded. Compromised data may include data collected after any disturbance of the sub-surface such as by drilling, excavation, soil sampling, etc. that may dramatically increase the mobility/solubility of some contaminants.

To demonstrate that there is little difference in the method used to calculate the baseline tolerance limit, values for the signature parameters at three of these locations were calculated using six methods (Table B-1). All of the data for each location were used in the calculations.

Table B-1 Calculated Baseline Tolerance Limits for MW-2032, MW-2046, and MW-2051

Location	Method	Ba (µg/l)	Fe (µg/l)	Mn (µg/l)	U (pCi/l)
MW-2032	EPA Guidance – Normal Data (a)	338.8	889.9	45.2	5.60
	Tolerance Limit – Normal Data (b)	376.7	1125.2	56.6	6.42
	xbar+3s – Normal Data	389.9	117.8	56.3	6.73
	EPA Guidance – log-Normal Data (a,c)	334.2	926.7	45.7	6.96
	Tolerance Limit – log-Normal Data (b,c)	370.7	1178.1	57.4	9.35
	xbar+3s – log-Normal Data (c)	383.4	1170.3	57.0	9.89
MW-2046	EPA Guidance – Normal Data (a)	256.5	1238.6	147.7	1.67
	Tolerance Limit – Normal Data (b)	276.7	1577.5	186.9	1.76
	xbar+3s – Normal Data	287.0	1566.9	185.7	1.84
	EPA Guidance – log-Normal Data (a,c)	249.9	1156.0	151.2	1.48
	Tolerance Limit – log-Normal Data (b,c)	268.3	1464.2	191.9	1.92
	xbar+3s – log-Normal Data (c)	277.6	1454.6	190.7	2.02
MW-2051	EPA Guidance – Normal Data (a)	253.2	2200.8	205.5	3.68
	Tolerance Limit – Normal Data (b)	285.3	2895.9	265.4	4.51
	xbar+3s – Normal Data	236.4	1657.9	158.7	3.12
	EPA Guidance – log-Normal Data (a,c)	248.5	1384.8	286.7	3.27
	Tolerance Limit – log-Normal Data (b,c)	278.9	1799.4	374.9	4.64
	xbar+3s – log-Normal Data (c)	232.6	1061.0	217.8	3.20

a Calculated by method outlined in EPA Addendum to Interim Final Guidance for Statistical Analysis of Ground-Water Monitoring at RCRA Facilities

b Bowker, Albert H. and Gerald J. Liberman, Engineering Statistics, Section 8.12 and 8.13.

c Mean and standard deviation for log-Normal calculated by method from Gilbert, Richard O., Statistical Methods for Environmental Pollution Monitoring, Section 13.1.1.

The method outlined in the EPA Guidance (Refs. B-1 and B-6) is designed to treat below detection limit values differently from other methods of calculating a benchmark or baseline tolerance limit where below detection limit values are typically set at one-half the detection limit. However, the EPA Guidance method assumes that all the below detection limit values have the same detection limit, which is seldom the case and complicates the analysis.

The values in the table for MW-2051 show more variation than the other locations, particularly for iron, manganese, and uranium. This is likely due to the small data sets, where only 5 or 6 values for each of the signature parameters have been collected, and one or two extreme or outlier values can skew the calculated value.

Comparison of the six different calculation methods yielded the following conclusions:

1. There is not much difference in the EPA Guidance Normal Data values and the EPA Guidance log-Normal Data values except for iron and manganese at MW-2051. Although the below detection limit values are treated the same in both these calculations, the difference is likely due to small sample size and outlier values as noted above.

2. The EPA Guidance Normal Data values and the Tolerance Limit Normal Data show some variation in many cases. The difference is probably attributable to the difference in the treatment of below detection limit values. The same argument can be stated for the EPA Guidance log-Normal Data values and the Tolerance Limit log-Normal Data values.

3. The Tolerance Limit Normal Data values and the "xbar+3s" Normal Data values are very similar, except at MW-2051. This is expected because the only difference is the tolerance factor multiplier. The Tolerance Limit is calculated as "xbar+ks", where the tolerance factor multiplier 'k' is from a table depending on the sample size and the probability that the calculated interval contains a give percent of the distribution. For the "xbar+3s" method the multiplier factor is always 3. The range for this factor is from approximately 2.2 to 10.5. As the sample size decrease the tolerance factor multiplier increases. This accounts for the difference in the values at MW-2051. The same argument can be stated for the Tolerance Limit log-Normal Data values and the "xbar+3s" log-Normal values.

Based on the analysis discussed above, it was not recommend to change the method currently used (tolerances limits) for calculation of benchmarks for the signature parameters. All of the available data that has not been compromised should be used. In addition, the 'arithmetic mean plus 3 standard deviations' is appropriate for the non-signature parameters since they are not a concern in the leachate.

B.5 References

B-1 U.S. Environmental Protection Agency, Office of Solid Waste, Waste Management Division. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities - Interim Final Guidance.* EPA/530-SW-89-026. Washington, D.C. April 1989.

B-2 MK-Ferguson Company and Jacobs Engineering Group. *Weldon Spring Site Environmental Report for Calendar Year 1998.* Rev. 0. DOE/OR/21548-773. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. Weldon Spring, Missouri. July 1999..

B-3 Tomasko, D., J. J. Quinn, L. A. Durham. *Groundwater Flow at the Chemical Plant Area of the Weldon Spring Site: Simulations of the Effect of the Disposal Cell on the Flow Field.* Prepared by Argonne National Laboratory, Environmental Assessment Division, Argonne, IL. October 1996.

B-4 MK-Ferguson Company and Jacobs Engineering Group. *Weldon Spring Site Environmental Report for Calendar Year 1999.* Rev. 0. DOE/OR/21548-845. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. Weldon Spring, Missouri. July 2000.

B-5 MK-Ferguson Company and Jacobs Engineering Group. *Weldon Spring Site Cell Groundwater Monitoring Demonstration Report.* Rev. 0. DOE/OR/21548-864. Prepared for the U.S. Department of Energy, Oak Ridge Operations Office. St. Charles, MO. November 2000.

B-6 U.S. Environmental Protection Agency, Office of Solid Waste, Waste Management Division. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities - Interim Final Guidance.* EPA/530-SW-93-001. Washington, D.C. November 1992.

TABLE 5. TOLERANCE FACTORS (K) FOR ONE-SIDED NORMAL TOLERANCE INTERVALS WITH PROBABILITY LEVEL (CONFIDENCE FACTOR) Y = 0.95 AND COVERAGE P = 95%

n	K	n	K
3	7.655	75	1.972
4	5.145	100	1.924
5	4.202	125	1.891
6	3.707	150	1.868
7	3.399	175	1.850
8	3.188	200	1.836
9	3.031	225	1.824
10	2.911	250	1.814
11	2.815	275	1.806
12	2.736	300	1.799
13	2.670	325	1.792
14	2.614	350	1.787
15	2.566	375	1.782
16	2.523	400	1.777
17	2.486	425	1.773
18	2.543	450	1.769
19	2.423	475	1.766
20	2.396	500	1.763
21	2.371	525	1.760
22	2.350	550	1.757
23	2.329	575	1.754
24	2.309	600	1.752
25	2.292	625	1.750
30	2.220	650	1.748
35	2.166	675	1.746
40	2.126	700	1.744
45	2.092	725	1.742
50	2.065	750	1.740
55	2.036	775	1.739
60	2.017	800	1.737
65	2.000	825	0.736
70	1.986	850	1.734
		875	1.733
		900	1.732
		925	1.731
		950	1.729
		975	1.728
		1000	1.727

SOURCE: (a) for sample sizes ≤ 50: Lieberman, Gerald F. 1958. "Tables for One-sided Statistical Tolerance Limits." *Industrial Quality Control.* Vol. XIV, No. 10. (b) for sample sizes ≥ 50: K values were calculated from large sample approximation.

U.S. Environmental Protection Agency, Office of Solid Waste, Waste Management Division. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities - Interim Final Guidance.* EPA/530-SW-89-026. Washington, D.C. April 1989.

APPENDIX C

Groundwater Flow Rate Determination

Groundwater Flow Rate Determination

Groundwater flow rates and flow directions will be evaluated annually as specified in Section 4.4 of the main text of this report. Results for 1998 through 2002 are presented in this appendix.

C.1 Groundwater Flow Direction

The groundwater flow direction was determined by constructing a potentiometric surface map of the shallow aquifer using the available wells at the chemical plant (Figure C-1). Potentiometric surface maps (Figures C-2 through C-6) were constructed using the average of the groundwater elevations measured during each year. A summary of the average groundwater elevations for each well is included in this appendix.

The potentiometric surface has remained relatively unchanged from 1998 through 2002. The groundwater flow direction is to the north. A groundwater divide is present along the southern boundary of the chemical plant site.

C.2 Groundwater Flow Rates

The calculation of the average groundwater flow rate (average linear velocity) is a function of the hydraulic conductivity (K), the hydraulic gradient (I) and the effective porosity (n_e) of the shallow aquifer:

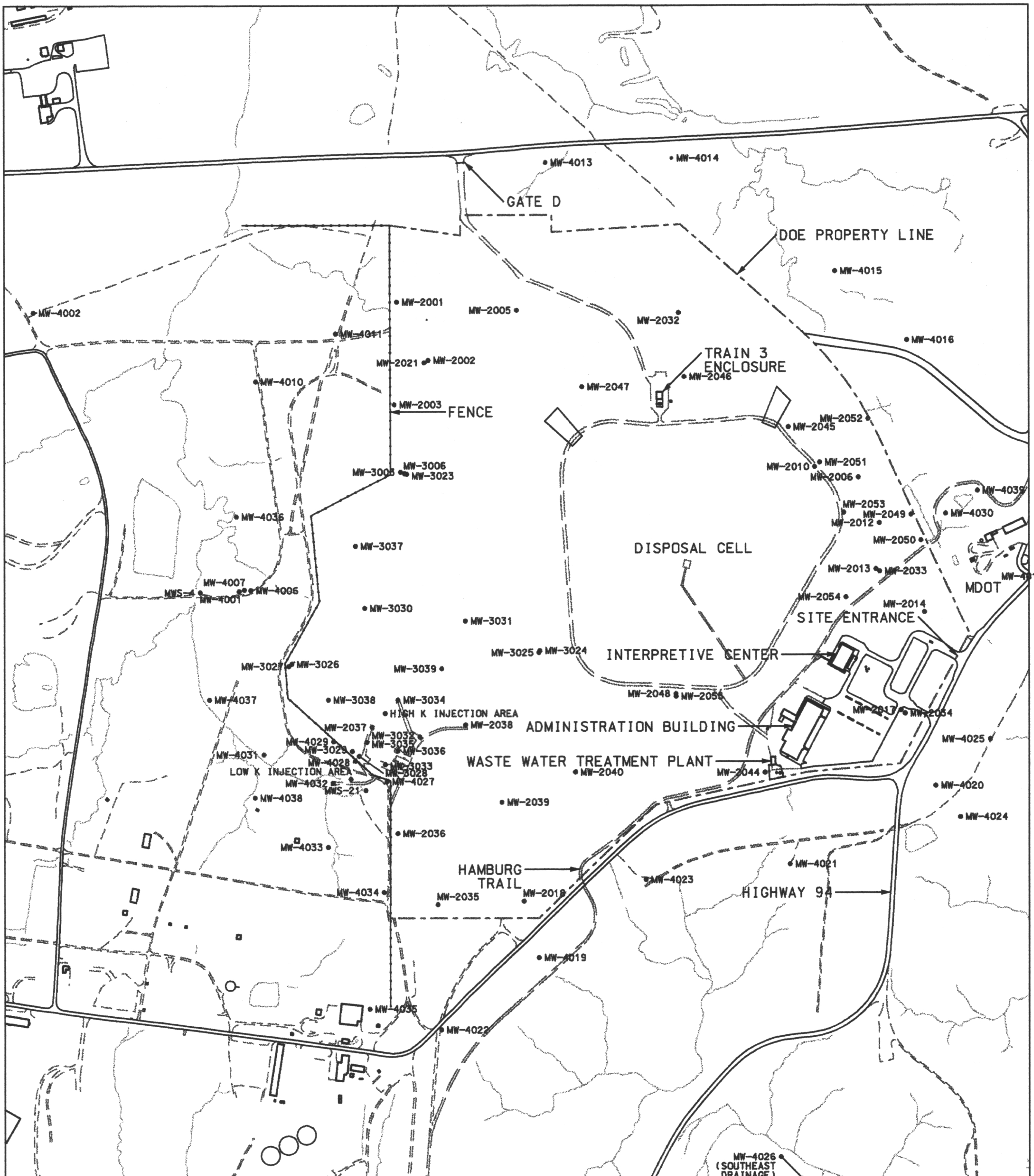
$$v = -Ki / n_e$$

The average groundwater flow rate for each year is summarized in Table C-1.

Table C-1 Average Groundwater Flow Rate From 1998 Through 2002

YEAR	Hydraulic Conductivity (cm/s) [1]	Effective Porosity [2]	GW Elevation		Hydraulic Gradient (ft/ft) [4]	Average Flow Rate (ft/day)
			MW-2048 [3]	MW-2032		
1998	0.007	0.10	607.5	582.9	0.012	2.4
1999			607.5	583.0	0.012	2.4
2000			607.5	582.9	0.012	2.4
2001			607.3	582.9	0.012	2.4
2002			606.8	582.9	0.011	2.2

1 Average hydraulic conductivity using data from the cell monitoring wells.
2 Value selected to estimate maximum groundwater flow rate.
3 Groundwater elevation from MW-2055 was used for 2002.
4 Horizontal distance between MW-2032 and MW-2048 is 2,100 ft.



• – MONITORING WELL

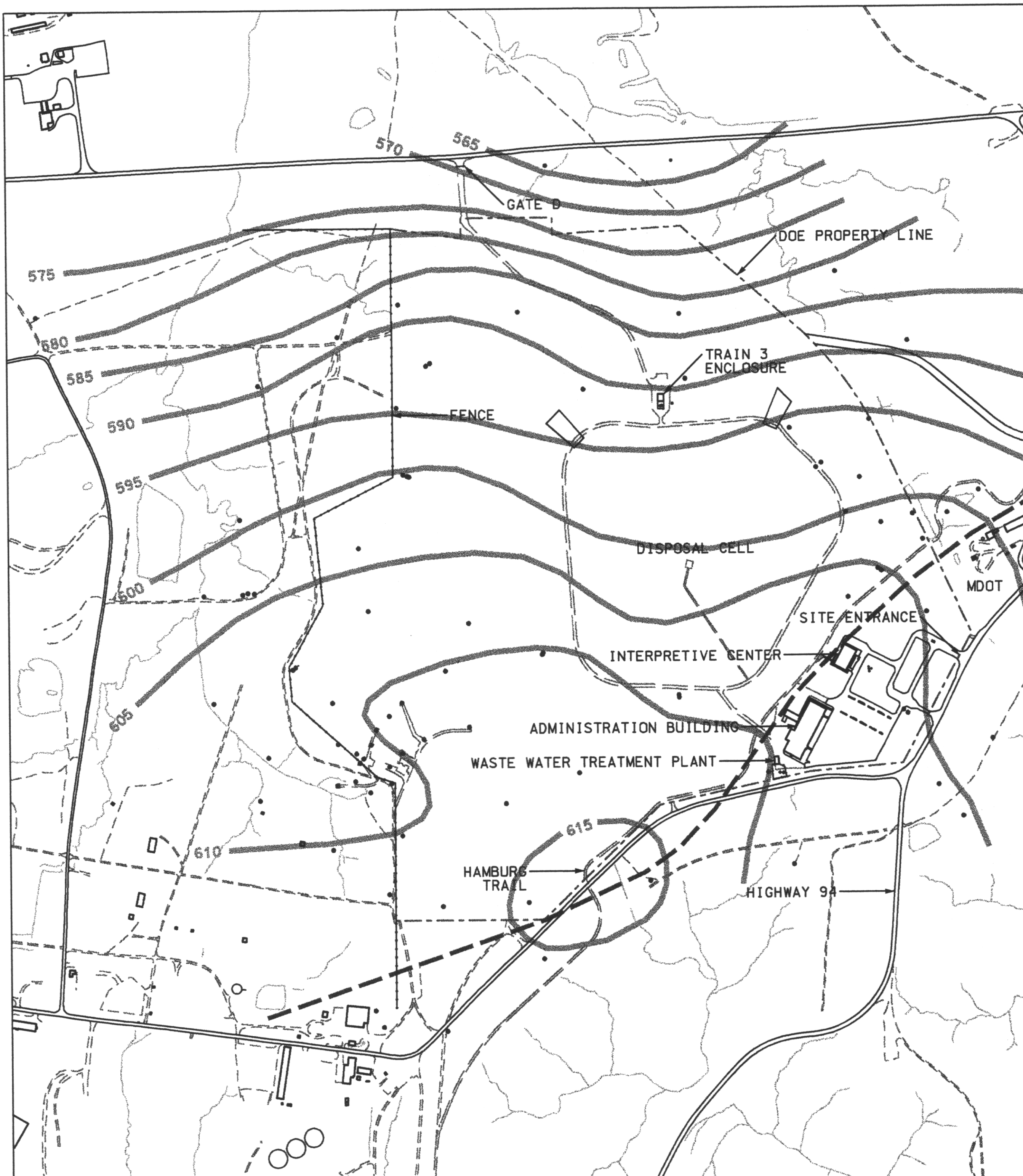
0 800 1600

SCALE FEET

MONITORING WELL NETWORK

FIGURE C-1

REPORT NO.: DOE/GJ/79491-646	EXHIBIT NO.: A/CP/016/0303	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 3/20/03



LEGEND

- • – MONITORING WELL
- – SURFACE WATER BODIES
- – STREAMS
- – GROUNDWATER DIVIDE
- 615 – POTENTIOMETRIC SURFACE (AVERAGE)

N

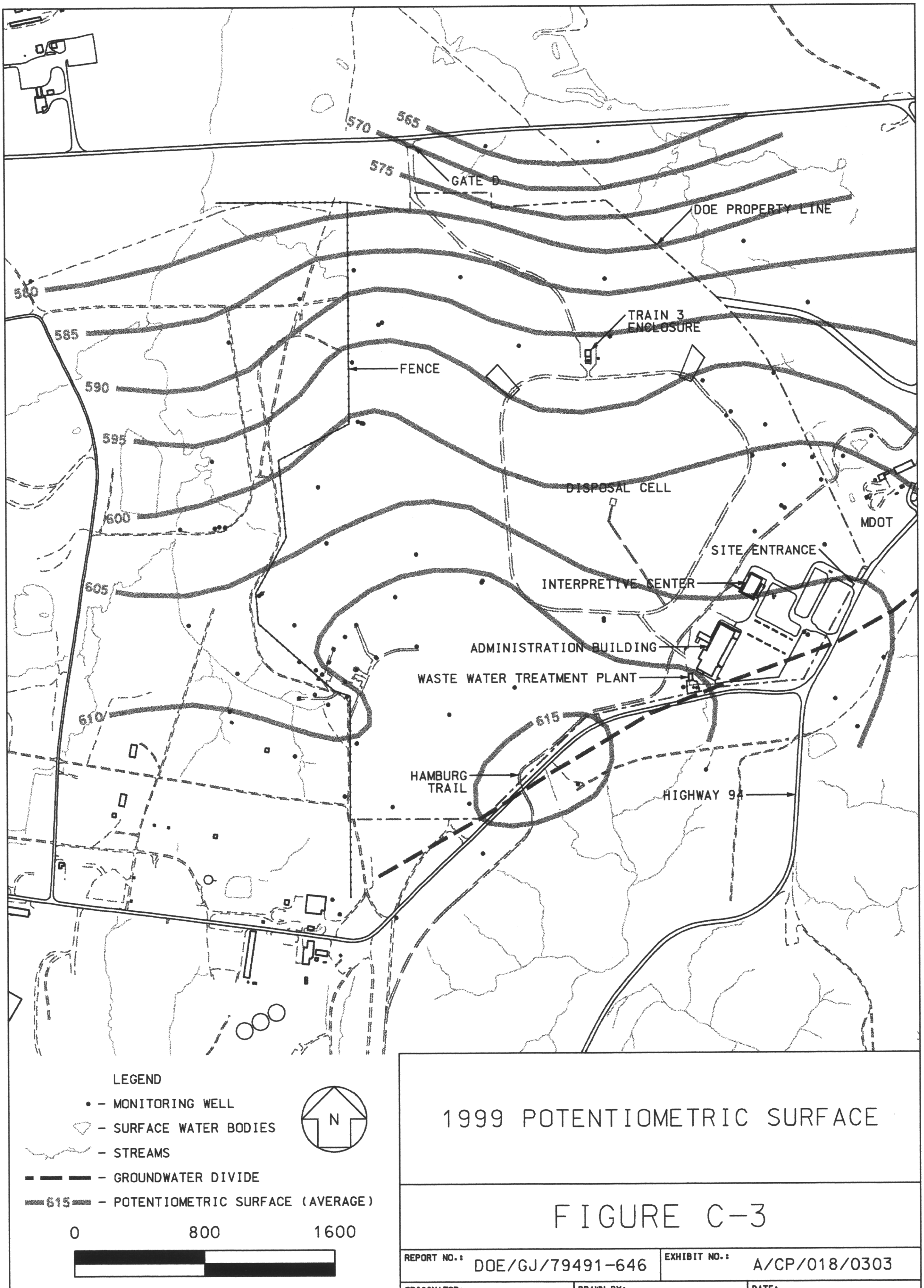
0 800 1600

SCALE FEET

1998 POTENTIOMETRIC SURFACE

FIGURE C-2

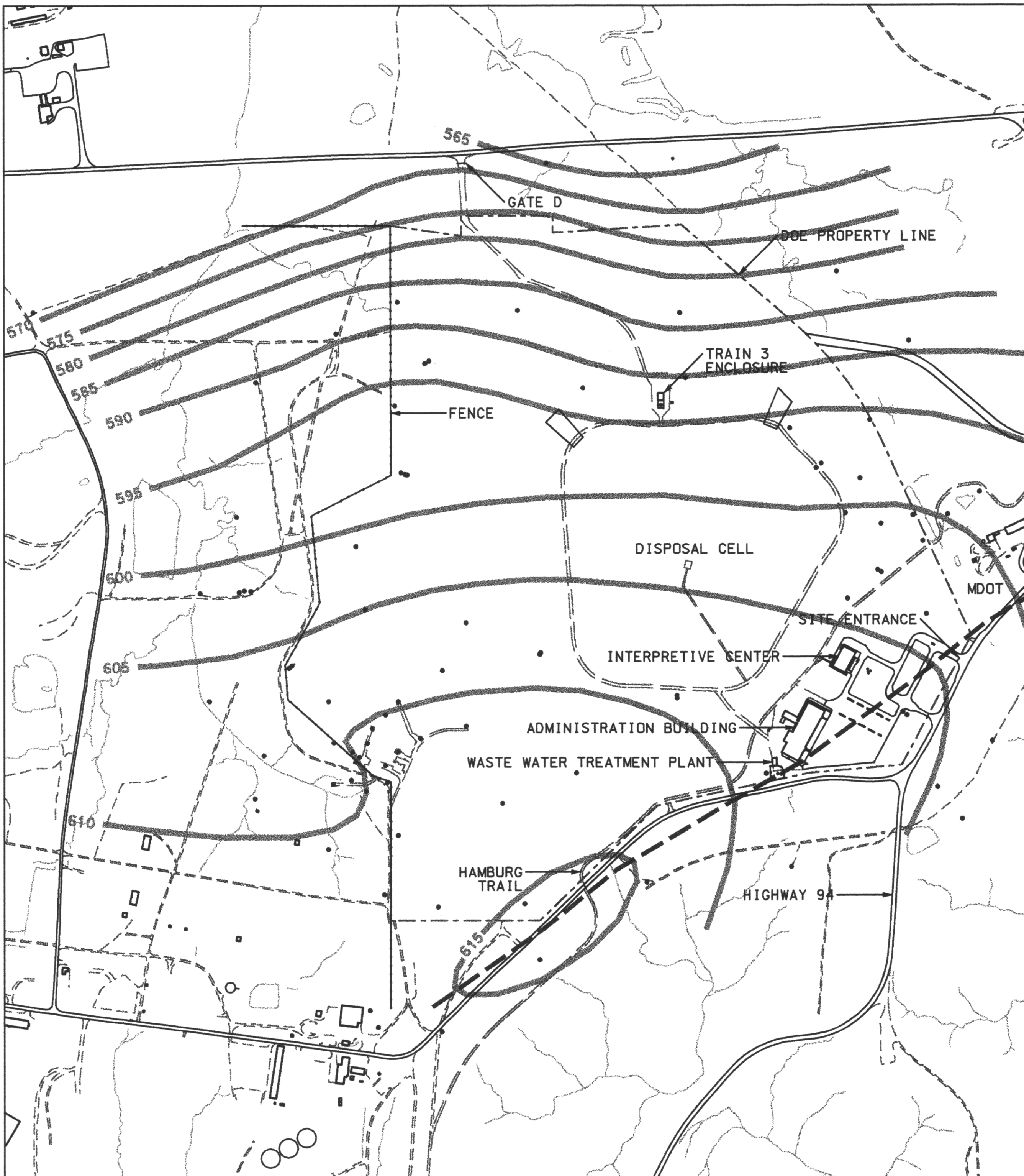
REPORT NO.: DOE/GJ/79491-646	EXHIBIT NO.: A/CP/017/0303	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 3/20/03



1999 POTENTIOMETRIC SURFACE

FIGURE C-3

REPORT NO.: DOE/GJ/79491-646		EXHIBIT NO.: A/CP/018/0303	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 3/20/03	



LEGEND

- • – MONITORING WELL
- – SURFACE WATER BODIES
- – STREAMS
- – GROUNDWATER DIVIDE
- 615 – POTENTIOMETRIC SURFACE (AVERAGE)

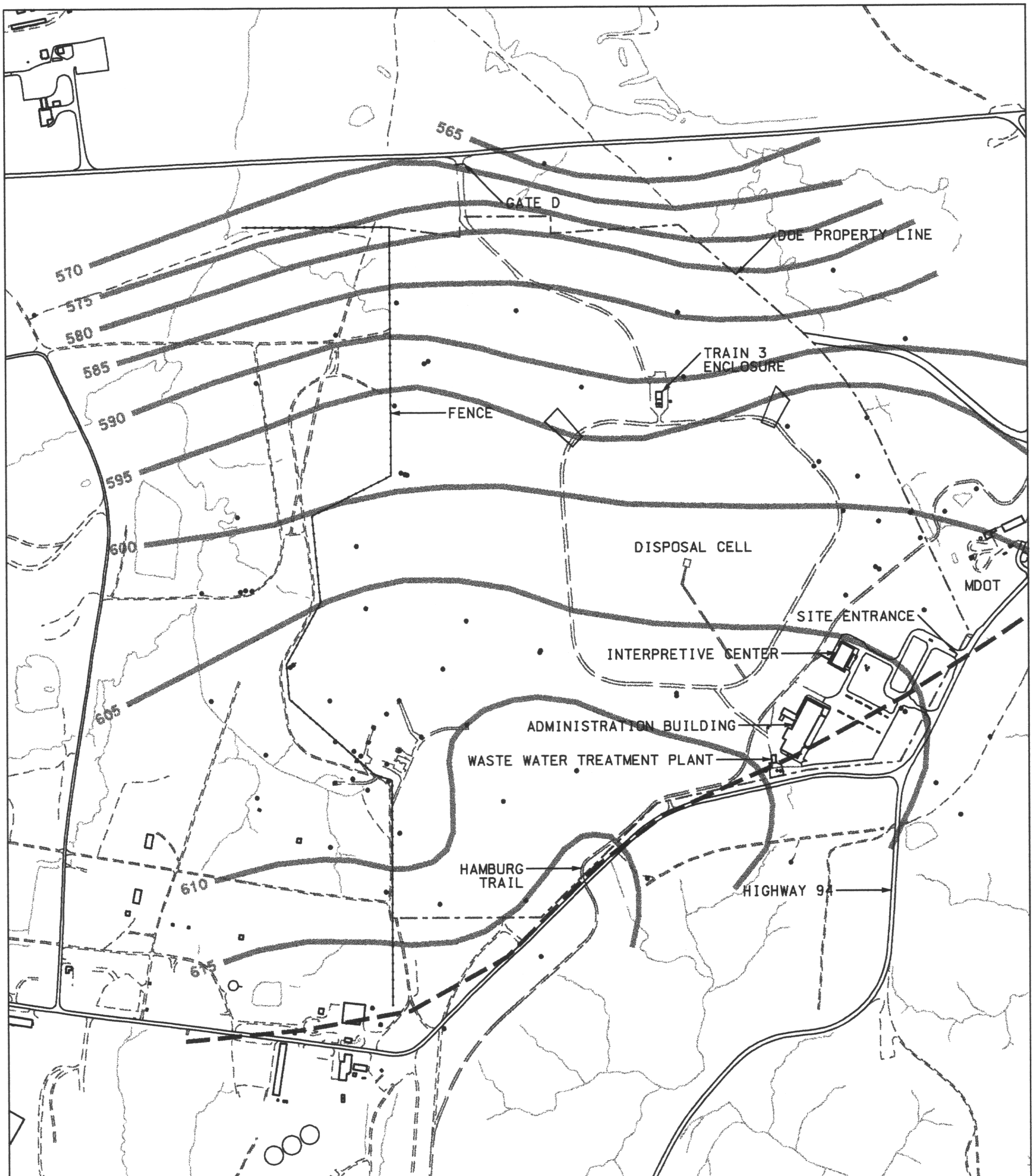
0 800 1600

SCALE FEET

2000 POTENTIOMETRIC SURFACE

FIGURE C-4

REPORT NO.: DOE/GJ/79491-646	EXHIBIT NO.: A/CP/019/0303	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 3/20/03



LEGEND

• – MONITORING WELL

– SURFACE WATER BODIES

– STREAMS

– GROUNDWATER DIVIDE

615 – POTENTIOMETRIC SURFACE (AVERAGE)

N

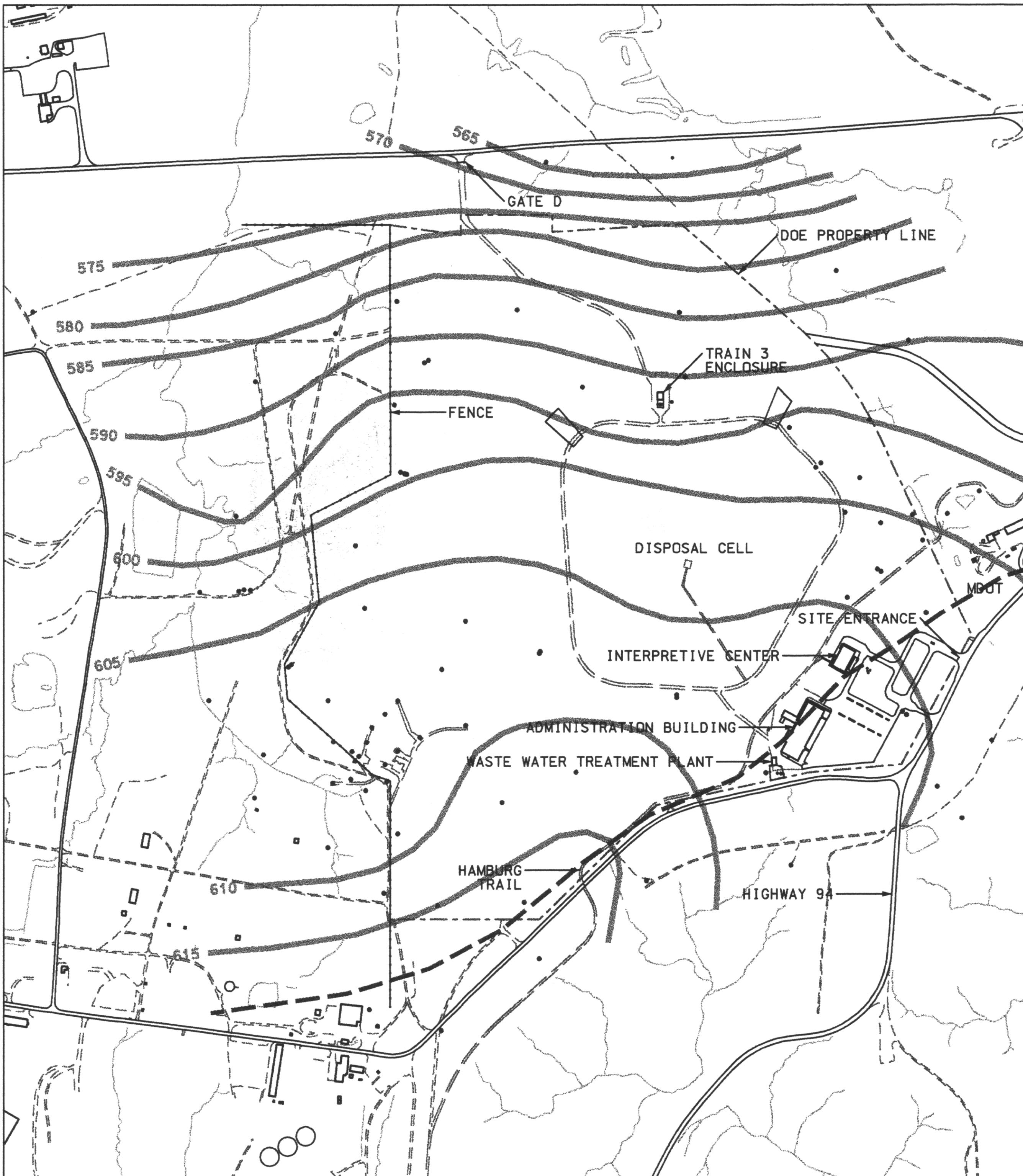
0 800 1600

SCALE FEET

2001 POTENTIOMETRIC SURFACE

FIGURE C-5

REPORT NO.: DOE/GJ/79491-646		EXHIBIT NO.: A/CP/020/0303	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 3/20/03	



LEGEND

- • – MONITORING WELL
- – SURFACE WATER BODIES
- – STREAMS
- – GROUNDWATER DIVIDE
- 615 – POTENTIOMETRIC SURFACE (AVERAGE)

N

0 800 1600

SCALE FEET

2002 POTENTIOMETRIC SURFACE

FIGURE C-6

REPORT NO.: DOE/GJ/79491-646		EXHIBIT NO.: A/CP/021/0303	
ORIGINATOR: RC	DRAWN BY: GLN	DATE: 3/20/03	

		YEAR				
LOCATION_	Data	1998	1999	2000	2001	2002
MW-2001	Average of WATER_ELEVATION	588.115	588.2175	587.9475	587.5625	588.0725
	Max of WATER_ELEVATION	588.73	588.58	588.48	587.69	588.43
	Min of WATER_ELEVATION	587.47	587.78	587.73	587.41	587.84
	Count of WATER_ELEVATION	4	4	4	4	4
MW-2002	Average of WATER_ELEVATION	593.214	592.9025	593.41	591.815	591.86
	Max of WATER_ELEVATION	593.99	593.51	594.3	592.68	592.29
	Min of WATER_ELEVATION	592.53	592.41	592.22	591.36	591.61
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2003	Average of WATER_ELEVATION	597.335	597.4875	597.0975	596.765	597.2525
	Max of WATER_ELEVATION	597.63	597.73	597.6	596.99	597.79
	Min of WATER_ELEVATION	596.98	597.19	596.33	596.47	596.79
	Count of WATER_ELEVATION	4	4	4	4	4
MW-2005	Average of WATER_ELEVATION	587.424	587.6	587.4175	587.233333	595.4425
	Max of WATER_ELEVATION	587.74	587.83	587.47	587.33	612.25
	Min of WATER_ELEVATION	587	587.44	587.38	587.16	589.79
	Count of WATER_ELEVATION	5	4	4	3	4
MW-2006	Average of WATER_ELEVATION	599.094	598.2475	597.62	598.545	598.05
	Max of WATER_ELEVATION	599.59	598.6	597.93	598.67	598.05
	Min of WATER_ELEVATION	598.67	598.01	597.22	598.29	598.05
	Count of WATER_ELEVATION	5	4	3	4	1
MW-2010	Average of WATER_ELEVATION	599.565				
	Max of WATER_ELEVATION	599.76				
	Min of WATER_ELEVATION	599.37				
	Count of WATER_ELEVATION	2				
MW-2012	Average of WATER_ELEVATION	602.936	601.0925	600.5925	600.9375	600.68
	Max of WATER_ELEVATION	604.2	601.28	600.72	601.07	600.81
	Min of WATER_ELEVATION	601.87	600.86	600.51	600.82	600.45
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2013	Average of WATER_ELEVATION	604.518	603.8475	603.1675	604.31	603.3725
	Max of WATER_ELEVATION	604.97	604.27	603.59	604.81	603.71
	Min of WATER_ELEVATION	604.15	603	602.73	604.03	602.72
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2014	Average of WATER_ELEVATION	603.934	603.5825	603.2625	603.7825	603.705
	Max of WATER_ELEVATION	604.2	603.84	603.55	604.05	603.91
	Min of WATER_ELEVATION	603.58	603.38	602.71	603.4	603.5
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2017	Average of WATER_ELEVATION	605.15	605.23	604.615	604.675	604.8425
	Max of WATER_ELEVATION	605.36	605.54	604.84	605.3	605.07
	Min of WATER_ELEVATION	604.71	604.85	604.32	604.06	604.61
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2018	Average of WATER_ELEVATION	615.482				
	Max of WATER_ELEVATION	615.82				
	Min of WATER_ELEVATION	614.87				
	Count of WATER_ELEVATION	5				
MW-2019	Average of WATER_ELEVATION	591.878				
	Max of WATER_ELEVATION	592.26				
	Min of WATER_ELEVATION	591.47				
	Count of WATER_ELEVATION	5				
MW-2021	Average of WATER_ELEVATION	589.256	589.1225	589.3025	588.27	588.6675
	Max of WATER_ELEVATION	589.98	589.66	591.44	588.5	589.21
	Min of WATER_ELEVATION	588.42	588.58	588.48	587.98	588.29
	Count of WATER_ELEVATION	5	4	4	4	4

MW-2022	Average of WATER_ELEVATION	585.07	585.31	584.99	590.95	586.145
	Max of WATER_ELEVATION	585.67	585.65	585.14	603.07	586.44
	Min of WATER_ELEVATION	584.58	585.07	584.71	584.74	586.01
	Count of WATER_ELEVATION	4	4	4	3	4
MW-2023	Average of WATER_ELEVATION	582.964	583.18	583.075	583.1025	583.19
	Max of WATER_ELEVATION	583.19	583.33	583.18	583.2	583.34
	Min of WATER_ELEVATION	582.4	583.11	582.96	582.99	583.08
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2024	Average of WATER_ELEVATION	566.956	567.255	566.67	566.6925	567.2875
	Max of WATER_ELEVATION	567.66	567.87	567	566.94	567.76
	Min of WATER_ELEVATION	566.2	566.88	566.49	566.16	566.83
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2026	Average of WATER_ELEVATION	590.855				
	Max of WATER_ELEVATION	591.18				
	Min of WATER_ELEVATION	590.53				
	Count of WATER_ELEVATION	2				
MW-2027	Average of WATER_ELEVATION	591.95				
	Max of WATER_ELEVATION	592.24				
	Min of WATER_ELEVATION	591.66				
	Count of WATER_ELEVATION	2				
MW-2032	Average of WATER_ELEVATION	582.886	583.01	582.8675	582.09	582.92
	Max of WATER_ELEVATION	583.09	583.49	582.9	582.09	582.92
	Min of WATER_ELEVATION	582.79	582.74	582.82	582.09	582.92
	Count of WATER_ELEVATION	5	4	4	1	1
MW-2033	Average of WATER_ELEVATION	605.096	604.645	604.52	605.08	604.34
	Max of WATER_ELEVATION	605.55	604.85	604.71	605.27	604.69
	Min of WATER_ELEVATION	604.69	604.32	604.27	604.82	603.44
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2034	Average of WATER_ELEVATION	606.302	606.495	605.61	605.63	605.6725
	Max of WATER_ELEVATION	606.81	606.71	605.68	606.6	606.11
	Min of WATER_ELEVATION	605.69	606.02	605.41	604.77	605.13
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2035	Average of WATER_ELEVATION	613.708	613.7275	613.2475	612.636667	615.7125
	Max of WATER_ELEVATION	614.08	613.97	613.36	612.91	615.79
	Min of WATER_ELEVATION	612.92	613.45	613.19	612.49	615.59
	Count of WATER_ELEVATION	5	4	4	3	4
MW-2036	Average of WATER_ELEVATION	610.552	610.755	609.9875	608.7975	609.4725
	Max of WATER_ELEVATION	611.57	610.91	610.21	610.21	609.61
	Min of WATER_ELEVATION	609.57	610.56	609.42	607.43	609.22
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2037	Average of WATER_ELEVATION	610.422	610.6875	610.19	609.42	609.51
	Max of WATER_ELEVATION	612.21	610.8	610.38	609.86	609.78
	Min of WATER_ELEVATION	608.62	610.53	610.09	608.98	609.17
	Count of WATER_ELEVATION	5	4	4	2	4
MW-2038	Average of WATER_ELEVATION	611.146	612.125	613.025	610.0675	609.9025
	Max of WATER_ELEVATION	611.87	614.65	619.63	611.1	610.06
	Min of WATER_ELEVATION	610.45	611.01	610.66	609.02	609.81
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2039	Average of WATER_ELEVATION	612.602	611.8925	612.45	615.13	611.24
	Max of WATER_ELEVATION	613.05	612.86	612.45	615.13	611.39
	Min of WATER_ELEVATION	611.86	609.6	612.45	615.13	611.05
	Count of WATER_ELEVATION	5	4	1	1	4

MW-2040	Average of WATER_ELEVATION	612.508	612.6325	611.933333	611.1675	611.065
	Max of WATER_ELEVATION	612.76	613.04	612.18	611.53	611.32
	Min of WATER_ELEVATION	612.21	612.31	611.71	610.74	610.91
	Count of WATER_ELEVATION	5	4	3	4	4
MW-2041	Average of WATER_ELEVATION	612.384	612.25	616.06		
	Max of WATER_ELEVATION	612.69	612.43	616.06		
	Min of WATER_ELEVATION	612.21	611.97	616.06		
	Count of WATER_ELEVATION	5	4	1		
MW-2042	Average of WATER_ELEVATION	613.822	613.4975	613.28		
	Max of WATER_ELEVATION	614.12	613.97	613.28		
	Min of WATER_ELEVATION	613.58	613.09	613.28		
	Count of WATER_ELEVATION	5	4	1		
MW-2043	Average of WATER_ELEVATION	611.088	613.2925	613.09		
	Max of WATER_ELEVATION	613.8	613.69	613.09		
	Min of WATER_ELEVATION	601.9	612.98	613.09		
	Count of WATER_ELEVATION	5	4	1		
MW-2044	Average of WATER_ELEVATION	613.805				
	Max of WATER_ELEVATION	613.84				
	Min of WATER_ELEVATION	613.77				
	Count of WATER_ELEVATION	2				
MW-2045	Average of WATER_ELEVATION	597.01	596.8625	596.48	599.355	596.65
	Max of WATER_ELEVATION	597.25	597	596.6	605.88	596.94
	Min of WATER_ELEVATION	596.5	596.64	596.4	597.08	596.44
	Count of WATER_ELEVATION	5	4	4	4	4
MW-2046	Average of WATER_ELEVATION	588.842	589	589.105	589.086667	589.01
	Max of WATER_ELEVATION	589.21	589.08	589.22	589.18	589.06
	Min of WATER_ELEVATION	588.25	588.92	589.02	589.02	588.93
	Count of WATER_ELEVATION	5	4	4	3	4
MW-2047	Average of WATER_ELEVATION	590.878	591.045	595.643333	590.9275	591.01
	Max of WATER_ELEVATION	591.21	591.11	604.91	590.97	591.08
	Min of WATER_ELEVATION	590.43	590.93	590.97	590.89	590.92
	Count of WATER_ELEVATION	5	4	3	4	4
MW-2048	Average of WATER_ELEVATION	607.54	607.51	607.485	607.343333	
	Max of WATER_ELEVATION	607.72	607.66	607.64	607.39	
	Min of WATER_ELEVATION	607.08	607.43	607.42	607.3	
	Count of WATER_ELEVATION	5	4	4	3	
MW-2049	Average of WATER_ELEVATION				599.5225	599.365
	Max of WATER_ELEVATION				599.6	599.47
	Min of WATER_ELEVATION				599.43	599.23
	Count of WATER_ELEVATION				4	4
MW-2050	Average of WATER_ELEVATION				601.1825	601.03
	Max of WATER_ELEVATION				601.35	601.13
	Min of WATER_ELEVATION				600.99	600.9
	Count of WATER_ELEVATION				4	4
MW-2051	Average of WATER_ELEVATION				598.94	598.88
	Max of WATER_ELEVATION				598.95	598.99
	Min of WATER_ELEVATION				598.93	598.79
	Count of WATER_ELEVATION				2	4
MW-2055	Average of WATER_ELEVATION					606.795
	Max of WATER_ELEVATION					606.93
	Min of WATER_ELEVATION					606.66
	Count of WATER_ELEVATION					4

MW-3003	Average of WATER_ELEVATION	598.5175	598.4475	598.05	597.5275	597.72
	Max of WATER_ELEVATION	599.22	598.85	598.11	597.86	597.95
	Min of WATER_ELEVATION	597.88	598.01	597.96	597.17	597.43
	Count of WATER_ELEVATION	4	4	4	4	4
MW-3006	Average of WATER_ELEVATION	592.5375	592.57	592.0475	591.1925	591.77
	Max of WATER_ELEVATION	593.5	593.08	592.74	591.45	592.35
	Min of WATER_ELEVATION	591.85	591.94	591.49	590.78	591.22
	Count of WATER_ELEVATION	4	4	4	4	4
MW-3019B	Average of WATER_ELEVATION	606.37				
	Max of WATER_ELEVATION	606.68				
	Min of WATER_ELEVATION	606.06				
	Count of WATER_ELEVATION	2				
MW-3023	Average of WATER_ELEVATION	600.935	601.17	598.3225	599.4375	599.8675
	Max of WATER_ELEVATION	601.74	601.27	600.34	599.96	599.9
	Min of WATER_ELEVATION	600.19	601.07	592.58	598.23	599.83
	Count of WATER_ELEVATION	4	4	4	4	4
MW-3024	Average of WATER_ELEVATION	601.28	601.74	599.9	600.5425	601.115
	Max of WATER_ELEVATION	601.64	602.38	600.77	600.95	601.65
	Min of WATER_ELEVATION	600.84	601.35	597.49	600.24	600.84
	Count of WATER_ELEVATION	4	3	4	4	4
MW-3025	Average of WATER_ELEVATION	610.1375	610.193333	609.235	608.1475	607.865
	Max of WATER_ELEVATION	610.4	610.33	609.52	608.78	608.06
	Min of WATER_ELEVATION	609.48	609.99	608.88	607.33	607.61
	Count of WATER_ELEVATION	4	3	4	4	4
MW-3026	Average of WATER_ELEVATION	607.3675	606.7475	605.8725	605.26	606.0375
	Max of WATER_ELEVATION	608.49	607.22	606.27	605.36	606.53
	Min of WATER_ELEVATION	606.14	606.39	605.05	605.14	605.67
	Count of WATER_ELEVATION	4	4	4	4	4
MW-3027	Average of WATER_ELEVATION	608.49	608.1425	607.9625	606.6825	607.005
	Max of WATER_ELEVATION	609.59	608.46	609.46	607.41	607.31
	Min of WATER_ELEVATION	607.66	607.89	607.31	606.36	606.7
	Count of WATER_ELEVATION	4	4	4	4	4
MW-3028	Average of WATER_ELEVATION	609.27	610.495	610.055	602.2625	609.2775
	Max of WATER_ELEVATION	610.17	610.62	610.19	609.72	609.45
	Min of WATER_ELEVATION	608.42	610.33	609.95	593.11	608.98
	Count of WATER_ELEVATION	3	4	4	4	4
MW-3029	Average of WATER_ELEVATION	609.146667	610.3725	609.9	607.515	609.15
	Max of WATER_ELEVATION	610.04	610.5	610.04	609.59	609.31
	Min of WATER_ELEVATION	608.3	610.21	609.77	604.89	608.84
	Count of WATER_ELEVATION	3	4	4	4	4
MW-3030	Average of WATER_ELEVATION				607.103333	607.425
	Max of WATER_ELEVATION				607.29	607.55
	Min of WATER_ELEVATION				606.87	607.3
	Count of WATER_ELEVATION				3	4
MW-3031	Average of WATER_ELEVATION				608.76	608.6025
	Max of WATER_ELEVATION				608.93	609.01
	Min of WATER_ELEVATION				608.51	608.01
	Count of WATER_ELEVATION				3	4
MW-3032	Average of WATER_ELEVATION				608.93	609.3525
	Max of WATER_ELEVATION				608.93	609.51
	Min of WATER_ELEVATION				608.93	609.11
	Count of WATER_ELEVATION				1	4

MW-3033	Average of WATER_ELEVATION				585.386667	
	Max of WATER_ELEVATION				587.7	
	Min of WATER_ELEVATION				582.38	
	Count of WATER_ELEVATION				3	
MW-3034	Average of WATER_ELEVATION				608.313333	609.245
	Max of WATER_ELEVATION				610.1	609.46
	Min of WATER_ELEVATION				606.07	608.96
	Count of WATER_ELEVATION				3	4
MW-3035	Average of WATER_ELEVATION				607.773333	609.2975
	Max of WATER_ELEVATION				608.97	609.48
	Min of WATER_ELEVATION				605.59	608.99
	Count of WATER_ELEVATION				3	4
MW-3036	Average of WATER_ELEVATION				607.976667	609.2925
	Max of WATER_ELEVATION				609.61	609.46
	Min of WATER_ELEVATION				605.54	609.01
	Count of WATER_ELEVATION				3	4
MW-3037	Average of WATER_ELEVATION					601.956667
	Max of WATER_ELEVATION					602.09
	Min of WATER_ELEVATION					601.78
	Count of WATER_ELEVATION					3
MW-3038	Average of WATER_ELEVATION					609.303333
	Max of WATER_ELEVATION					609.4
	Min of WATER_ELEVATION					609.16
	Count of WATER_ELEVATION					3
MW-3039	Average of WATER_ELEVATION					608.82
	Max of WATER_ELEVATION					608.89
	Min of WATER_ELEVATION					608.76
	Count of WATER_ELEVATION					3
MW-4001	Average of WATER_ELEVATION	602.814	602.1575	601.5775	601.7725	602.48
	Max of WATER_ELEVATION	603.71	602.72	601.89	602.85	603.83
	Min of WATER_ELEVATION	601.8	601.54	601.28	601.1	601.87
	Count of WATER_ELEVATION	5	4	4	4	4
MW-4002	Average of WATER_ELEVATION	575.842	570.5225	568.86	570.436667	577.0675
	Max of WATER_ELEVATION	584.9	576.37	569.15	573.8	587.56
	Min of WATER_ELEVATION	568.16	568.27	568.71	568.75	568.8
	Count of WATER_ELEVATION	5	4	4	3	4
MW-4003	Average of WATER_ELEVATION	614.318	615.08			
	Max of WATER_ELEVATION	615.28	615.08			
	Min of WATER_ELEVATION	612.61	615.08			
	Count of WATER_ELEVATION	5	1			
MW-4004	Average of WATER_ELEVATION	612.094	612.12			
	Max of WATER_ELEVATION	612.66	612.12			
	Min of WATER_ELEVATION	611.56	612.12			
	Count of WATER_ELEVATION	5	1			
MW-4005	Average of WATER_ELEVATION	610.19	610.31			
	Max of WATER_ELEVATION	610.96	610.31			
	Min of WATER_ELEVATION	609.32	610.31			
	Count of WATER_ELEVATION	5	1			
MW-4006	Average of WATER_ELEVATION	602.938	602.1175	601.61	601.5025	602.26
	Max of WATER_ELEVATION	603.74	602.46	601.84	601.75	603.33
	Min of WATER_ELEVATION	602.27	601.64	601.4	601.14	601.66
	Count of WATER_ELEVATION	5	4	4	4	4

MW-4007	Average of WATER_ELEVATION	596.358	596.0175	594.8825	594.4625	595.325
	Max of WATER_ELEVATION	597.25	596.67	595.01	594.91	596.38
	Min of WATER_ELEVATION	595.68	595.15	594.65	593.93	594.48
	Count of WATER_ELEVATION	5	4	4	4	4
MW-4008	Average of WATER_ELEVATION	597.67	598.1			
	Max of WATER_ELEVATION	598.38	598.1			
	Min of WATER_ELEVATION	597.01	598.1			
	Count of WATER_ELEVATION	5	1			
MW-4009	Average of WATER_ELEVATION	594.2	594.73			
	Max of WATER_ELEVATION	595.45	594.73			
	Min of WATER_ELEVATION	593.21	594.73			
	Count of WATER_ELEVATION	5	1			
MW-4010	Average of WATER_ELEVATION	589.39	590.54			
	Max of WATER_ELEVATION	591.04	590.54			
	Min of WATER_ELEVATION	588.02	590.54			
	Count of WATER_ELEVATION	5	1			
MW-4011	Average of WATER_ELEVATION	592.01	591.935	591.9275	591.5875	592.76
	Max of WATER_ELEVATION	592.79	592.45	592.93	591.86	593.3
	Min of WATER_ELEVATION	591.32	591.3	591.17	591.27	591.76
	Count of WATER_ELEVATION	5	4	4	4	4
MW-4012	Average of WATER_ELEVATION	570.8725	571.08			
	Max of WATER_ELEVATION	571.25	571.08			
	Min of WATER_ELEVATION	570.72	571.08			
	Count of WATER_ELEVATION	4	1			
MW-4013	Average of WATER_ELEVATION	560.2375	560.2525	561.0325	561.0625	560.4125
	Max of WATER_ELEVATION	560.38	560.33	563.2	563.35	560.5
	Min of WATER_ELEVATION	560.16	560.22	560.22	560.29	560.36
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4014	Average of WATER_ELEVATION	560.4875	560.6375	560.5975	560.9825	561.23
	Max of WATER_ELEVATION	561.02	561.06	561.05	561.1	561.66
	Min of WATER_ELEVATION	560.21	560.33	560.07	560.8	561.04
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4015	Average of WATER_ELEVATION	581.39	581.47	580.8175	581.74	581.9575
	Max of WATER_ELEVATION	582.51	582.53	580.98	581.98	583.01
	Min of WATER_ELEVATION	580.65	580.87	580.64	581.51	581.34
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4016	Average of WATER_ELEVATION	589.14	589.25			
	Max of WATER_ELEVATION	589.42	589.25			
	Min of WATER_ELEVATION	588.82	589.25			
	Count of WATER_ELEVATION	4	1			
MW-4018	Average of WATER_ELEVATION	598.095	598.08			
	Max of WATER_ELEVATION	598.56	598.08			
	Min of WATER_ELEVATION	597.46	598.08			
	Count of WATER_ELEVATION	4	1			
MW-4019	Average of WATER_ELEVATION	613.105				
	Max of WATER_ELEVATION	613.26				
	Min of WATER_ELEVATION	612.95				
	Count of WATER_ELEVATION	2				
MW-4020	Average of WATER_ELEVATION	604.9875	605.26	604.2475	604.06	604.6225
	Max of WATER_ELEVATION	605.3	605.73	604.43	604.32	604.89
	Min of WATER_ELEVATION	604.4	604.83	604.02	603.59	604.24
	Count of WATER_ELEVATION	4	4	4	3	4

MW-4021	Average of WATER_ELEVATION	607.516667				
	Max of WATER_ELEVATION	607.65				
	Min of WATER_ELEVATION	607.32				
	Count of WATER_ELEVATION	3				
MW-4022	Average of WATER_ELEVATION	596.65	597.105	594.18	593.3225	594.0825
	Max of WATER_ELEVATION	597.22	597.62	594.67	593.49	595.69
	Min of WATER_ELEVATION	595.6	596.54	593.78	592.95	592.81
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4023	Average of WATER_ELEVATION	615.5125	615.37	614.7725	614.5775	614.5025
	Max of WATER_ELEVATION	615.95	615.64	614.94	615.08	615.07
	Min of WATER_ELEVATION	614.7	614.98	614.58	613.87	613.93
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4024	Average of WATER_ELEVATION	605.09	605.3525	604.2375	603.893333	604.5025
	Max of WATER_ELEVATION	605.45	605.86	604.38	604.18	604.84
	Min of WATER_ELEVATION	604.46	604.89	604.08	603.34	604.04
	Count of WATER_ELEVATION	4	4	4	3	4
MW-4025	Average of WATER_ELEVATION	604.9475	604.87			
	Max of WATER_ELEVATION	605.83	604.87			
	Min of WATER_ELEVATION	604.07	604.87			
	Count of WATER_ELEVATION	4	1			
MW-4026	Average of WATER_ELEVATION	459.89	459.9325	459.6	459.68	459.7525
	Max of WATER_ELEVATION	460.06	460.51	459.82	459.83	460.13
	Min of WATER_ELEVATION	459.65	459.51	459.38	459.53	459.15
	Count of WATER_ELEVATION	6	4	2	2	4
MW-4027	Average of WATER_ELEVATION	609.326667	610.5	610.0575	609.38	609.2825
	Max of WATER_ELEVATION	610.23	610.64	610.22	609.97	609.41
	Min of WATER_ELEVATION	608.41	610.42	609.93	608.79	609.03
	Count of WATER_ELEVATION	3	4	4	2	4
MW-4028	Average of WATER_ELEVATION	609.5025	610.6125	609.785	607.6625	609.34
	Max of WATER_ELEVATION	610.18	611.02	610.03	609.72	609.73
	Min of WATER_ELEVATION	608.57	610.38	609.2	605.22	608.98
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4029	Average of WATER_ELEVATION	609.465	610.435	610.0225	608.0775	609.2475
	Max of WATER_ELEVATION	610.15	610.58	610.19	609.7	609.42
	Min of WATER_ELEVATION	608.55	610.35	609.87	605.85	608.95
	Count of WATER_ELEVATION	4	4	4	4	4
MW-4030	Average of WATER_ELEVATION				597.1625	597.21
	Max of WATER_ELEVATION				597.29	597.36
	Min of WATER_ELEVATION				597.06	597.13
	Count of WATER_ELEVATION				4	4
MW-4031	Average of WATER_ELEVATION				608.366667	609.3725
	Max of WATER_ELEVATION				608.66	609.61
	Min of WATER_ELEVATION				608.03	609.24
	Count of WATER_ELEVATION				3	4
MW-4032	Average of WATER_ELEVATION				608.54	609.5
	Max of WATER_ELEVATION				608.88	609.72
	Min of WATER_ELEVATION				608.2	609.25
	Count of WATER_ELEVATION				2	4
MW-4033	Average of WATER_ELEVATION				608.5	609.3
	Max of WATER_ELEVATION				608.72	609.42
	Min of WATER_ELEVATION				608.28	609.06
	Count of WATER_ELEVATION				2	4

MW-4034	Average of WATER_ELEVATION				610.71	611.1525
	Max of WATER_ELEVATION				610.78	611.21
	Min of WATER_ELEVATION				610.64	611.02
	Count of WATER_ELEVATION				2	4
MW-4035	Average of WATER_ELEVATION				623.24	623.8925
	Max of WATER_ELEVATION				623.42	624.08
	Min of WATER_ELEVATION				623.06	623.43
	Count of WATER_ELEVATION				2	4
MW-4036	Average of WATER_ELEVATION					592.51
	Max of WATER_ELEVATION					593.23
	Min of WATER_ELEVATION					591.63
	Count of WATER_ELEVATION					4
MW-4037	Average of WATER_ELEVATION					608.2525
	Max of WATER_ELEVATION					609.61
	Min of WATER_ELEVATION					607.19
	Count of WATER_ELEVATION					4
MW-4038	Average of WATER_ELEVATION					609.51
	Max of WATER_ELEVATION					609.64
	Min of WATER_ELEVATION					609.23
	Count of WATER_ELEVATION					4
MWS-21	Average of WATER_ELEVATION	609.33875	606.25	609.89	608.44	609.4075
	Max of WATER_ELEVATION	610.28	610.47	609.89	610.28	609.68
	Min of WATER_ELEVATION	608.93	602.03	609.89	606.6	609.19
	Count of WATER_ELEVATION	8	2	1	4	4
MWS-3	Average of WATER_ELEVATION	594.303333	598.915			
	Max of WATER_ELEVATION	594.73	603.11			
	Min of WATER_ELEVATION	593.97	594.72			
	Count of WATER_ELEVATION	3	2			
MWS-4	Average of WATER_ELEVATION	602.581429	602.675	601.39	601.556667	602.41
	Max of WATER_ELEVATION	602.94	602.85	601.39	601.94	603.53
	Min of WATER_ELEVATION	601.62	602.5	601.39	601.12	601.84
	Count of WATER_ELEVATION	7	2	1	3	4

Appendix L
Well Field Contingency Plan

L1.0 Planning and Preparation

Under this contingency plan, which supersedes the *Well Field Contingency Plan* (DOE 1992b), any production capacity lost to the existing well field due to confirmed contaminant migration from the Weldon Spring quarry will be replaced. While it is highly unlikely that such measures will be implemented, this plan defines the minimum planning and preparation required to facilitate a rapid and effective response. Planning and preparation measures include the following:

- Selection of a reliable alternate source of water to replace or supplement the existing well field.

- Preparation of a plan for data collection to facilitate development of the selected alternate source.

- Development of design criteria for use in design and construction of the alternate source infrastructure.

L1.1 Selection of Alternate Source

Criteria and alternatives for contingency planning were developed using modified value engineering principles. Modified value engineering is an alternative evaluation process that parallels the CERCLA philosophy of remedial alternative development that is not based upon cost unless all other criteria (i.e., effectiveness, implementability, etc.) are equal. This process was performed as outlined in *Alternative Evaluation Study Manual* (DOE 2000).

Two broad potential scenarios were considered as part of alternative evaluation: (1) a portion of the well field is threatened, requiring partial replacement of the water supply; and (2) the entire well field is threatened, requiring replacement of the entire water supply from the existing well field.

The criteria used to evaluate the alternatives were effectiveness, technical feasibility, degree of disruption, public acceptance, regulatory requirements, cost, and impact on the present treatment system. By applying these criteria, all but the top three alternatives for each scenario were quickly eliminated (Table L−1). Further evaluation of the remaining alternatives led to the selection of a proposed alternative. The evaluation and selection process is described in the report *St. Charles County Well Field Summary of Alternatives for Contingency Plans* (DOE 1992a).

Table L−1. Alternatives Considered for Water Supply Replacement Scenarios

Alternative	Rank of Alternative	
	Partial Replacement Scenario	**Full Replacement Scenario**
New well(s) in existing well field	2	7
New well(s) in Darst Bottoms upstream of existing well field	1	1
Modify existing well system	10	10
Change pumping scheme of existing wells	6	9
Utilize existing pipeline from St. Louis	5	11
New pipeline to Howard Bend Plant	4	3
Treat Missouri River surface water	3	2
Find bedrock source of water at another site	7	6
Treat and use contaminated water	11	8
Protect well field with a slurry wall	8	4
Redirection of existing capacities	9	5
No action	Not appropriate	Not appropriate

The selected alternative is the installation of additional water supply wells in the Darst Bottoms to the south of the present well field (Figure L−1). Although this location is within the same aquifer as the present well field, the replacement location is upgradient of the contaminant source, the Weldon Spring quarry. Hence, given that action levels for contaminants are conservative (low), the replacement well field location would be unaffected by contaminant migration either from the quarry or a potentially tainted well field to the north.

L1.2 Preparation of a Plan for Hydrogeologic Investigation

A plan will be prepared for a hydrogeologic investigation required to obtain the information necessary to develop the alternate source of ground water. This plan will identify the activities, sampling, and testing required to assess the hydrogeologic characteristics of the replacement well field area. While the hydrogeologic characteristics of the replacement well field location are probably quite similar to the present well field, additional data and testing will be required to ensure an adequate assessment, and to ensure that engineering design is optimized to meet production needs.

L1.3 Design Criteria

Engineering design criteria will be established for use in design and construction of the alternate water supply. Design criteria will address:

- Functional requirements relative to interface with the existing well field and treatment plant.
- Performance requirements relative to production capacity.
- Phased response (requirements for partial versus full replacement).
- Water quality requirements.
- Well sitting and construction.

In the event an alternate source of drinking water is required, engineering design and construction shall proceed based on the design criteria established under this plan.

L1.4 Access

Should the need arise, access for data collection purposes, well installation, and pipe line construction will be coordinated with the affected private landowners and St. Charles County officials. As an interim measure, private landowners who would be affected by construction of a replacement well field were contacted by a U.S. Department of Energy (DOE) representative who explained the contingency plan and outlined the potential for a request for access to be made at some future time.

L1.5 Installation of Replacement Wells

In the event that contaminants from the Weldon Spring quarry are detected above action levels established under this plan, the following steps will be taken to install a replacement well field:

- Access will be obtained from affected landowners.
- Subcontractor services will be procured for drilling of production and test wells and acquisition of other data prescribed as part of the hydrogeologic investigation.
- Field activities will be initiated as detailed in the hydrogeologic investigation plan.
- Design of components necessary to perform drilling, install wells, pumps, and piping, and construct pumping facilities and controls will be accelerated.
- Procurement of materials will be accelerated for pumps, piping, casing, screens, and all appurtenances required to complete construction of the replacement well field to production standards.
- The replacement well field will be installed under the direction of DOE.

L1.6 Permits

Construction permits would be required from the MDNR and St. Charles County as well as a permit from the Darst Bottoms Levee District in order to install the replacement wells. The permit process is estimated to take between 60 and 90 days (DOE 1992b).

L1.7 Schedule

Assuming that construction would proceed on several tasks simultaneously, it is estimated that a minimum of 2 months will be required for construction after permits are obtained. Allowing 60 days for engineering and the preparation of permit applications, about 200 days would be required from the start of engineering through the start up of the pumps (DOE 1992b). The estimated implementation schedule is illustrated in Figure L−2.

During the period of time required to complete installation of the replacement well field, the present well field would operate without the reserve provided by the affected wells. In a worst case scenario, the present well field might not meet production demands during the period of new well field construction. In this instance, service demands for St. Charles County Plant No. 1 would have to be met through an alternate source or rationing (such as water used for lawn care and car washing, etc.) until the replacement well field went on line or demand subsided due to the normal demand cycle.

L1.8 Well Design

Figure L−3 illustrates the preliminary design of the replacement wells.

L2.0 References

U.S. Department of Energy (DOE), 1992a. *St. Charles County Well Field Summary of Alternatives for Contingency Plans,* DOE/OR/21548-285, prepared by L.G. Zambrana Consultants, Inc. and Woodward-Clyde Consultants for the U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, May.

-------, 1992b. *Well Field Contingency Plan,* DOE/OR/21548-340, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, November.

-------, 2000. *Alternative Evaluation Study Manual,* Rev. 1, DOE/OR/21548-640, U.S. Department of Energy Oak Ridge Operations Office, Weldon Spring Site Remedial Action Project, Weldon Spring, Missouri, January.

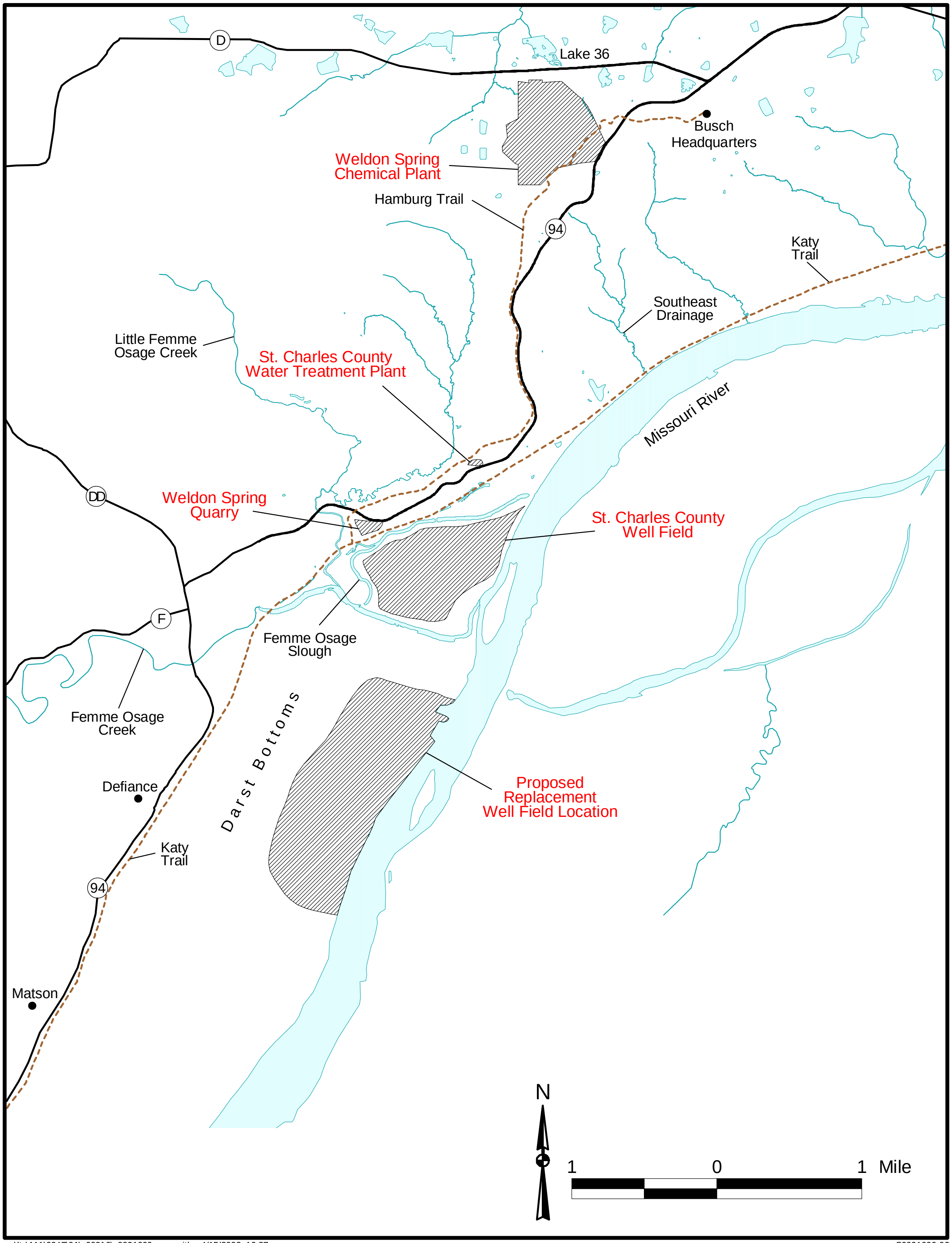


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Figure L−1. Proposed Replacement Well Field Location

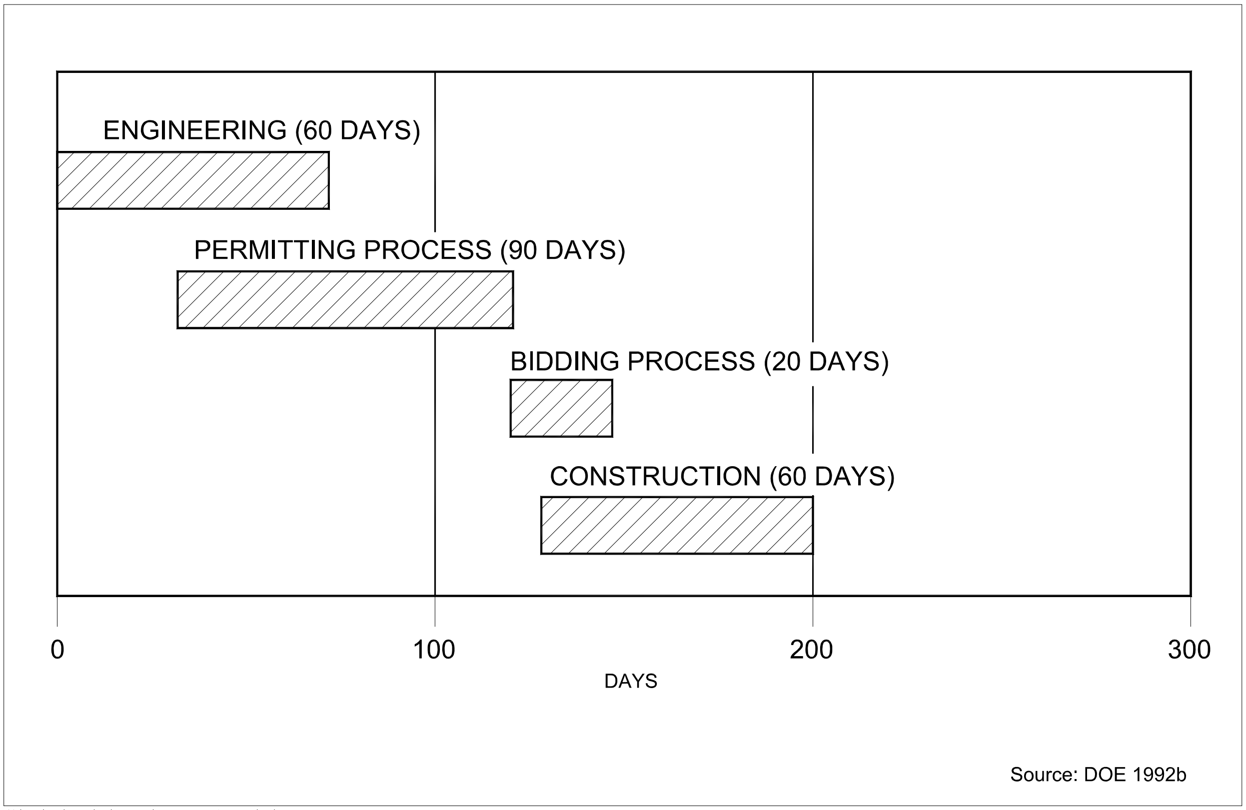

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Figure L−2. Estimated Replacement Well field Installation Schedule

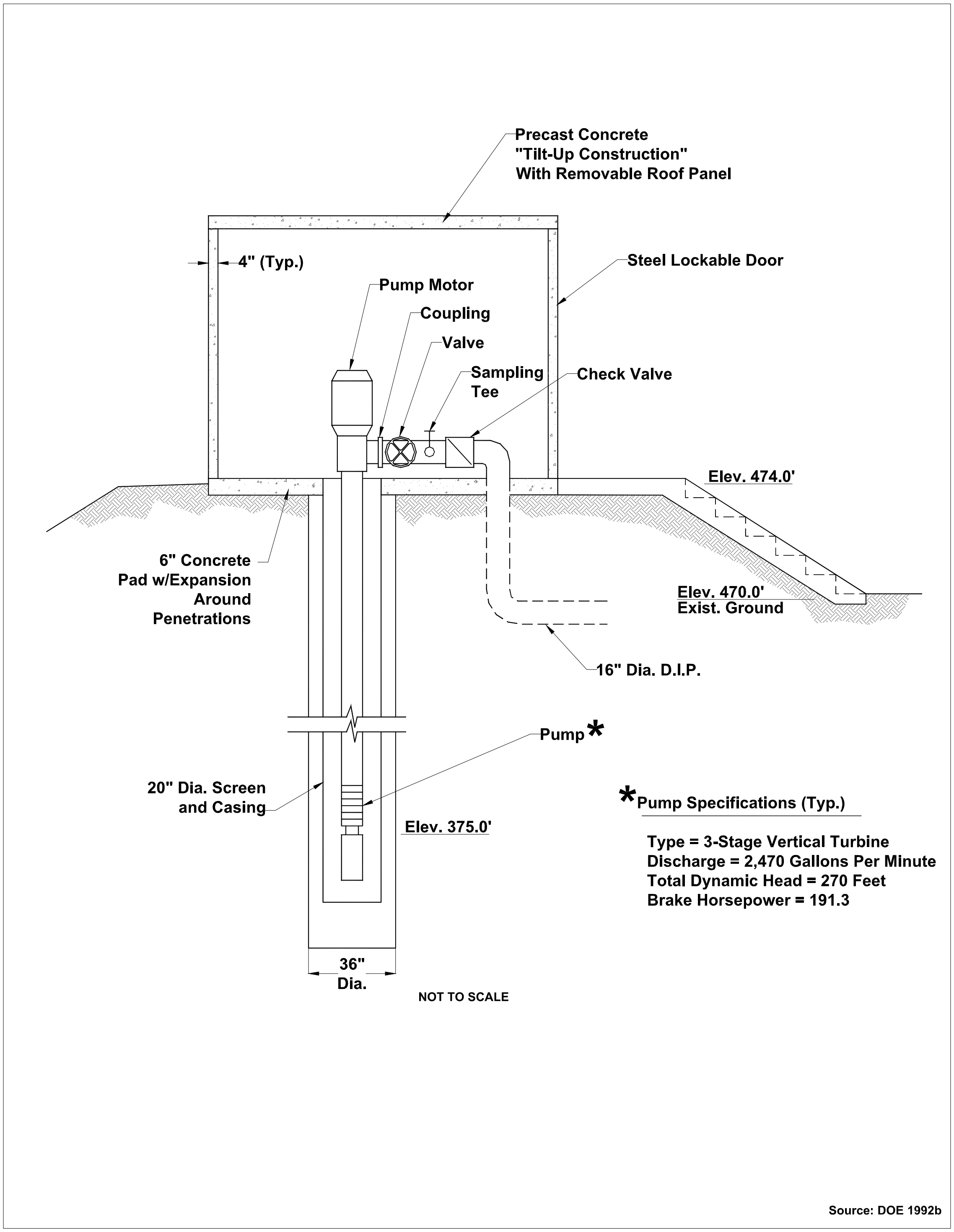

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Figure L−3. Proposed Typical Replacement Well Schematic

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